THE ECONOMICS OF INFORMATION

- economic analysis applied to the evaluation of documentary information systems

Aldo de Albuquerque Barreto

Dissertation submitted for the degree of Doctor of Philosophy

Centre for Information Science
The City University
London EC1

April 1982

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES AND FIGURES

LIST OF APPENDICES

ACKNOWLEDGEMENTS

This research would never be possible without the support of two persons and two organizations.

I am greatly obliged to my adviser Dr. R.T. Bottle for his help, advice and constant motivation. I am also grateful to Mrs. Abigail de Carvalho from IBICT (Brazil) for her ever present interest in this work.

I must acknowledge the financial support of CNPq - Conselho Nacional para o Desenvolvimento Cientifico e Tecnologico (Brazil) and of The British Council which made possible this research project.

DECLARATION

PERMISSION TO COPY THE WHOLE OR PART OF THIS THESIS FOR THE PURPOSES OF PRIVATE STUDY MAY BE GRANTED AT THE DISCRETION OF THE UNIVERSITY LIBRARIAN OF THE CITY UNIVERSITY, SUBJECT TO NORMAL CONDITIONS OF ACKNOWLEDGEMENT.

ABSTRACT

The use of economic analysis is suggested for decisions relating to services provided by documentary information systems. Ragnar Frisch's Theory of Production model is used in the analysis. An information system is viewed as a production system, with input elements and the final product, the output, defined as the information received by the user, which could be measured in terms of volume. The research divides in two parts - a) The cost study and b) The economic evaluation. It is suggested that costs compiled by traditional accounting procedures have little value as a guide to management decisions. Average cost analysis, or unit costs, based only on the volume of output as the variable affecting costs is shown to be an over-simplified approach. Costs seem to be affected by several operational conditions found in information systems. An attempt is made to identify which variables affects cost behaviour. As criteria for decision making - cost-effectiveness and cost-benefit analysis - do not seem sufficient for the evaluation of documentary information systems. Cost-effectiveness analysis, a value for money calculation, is only a method of making comparisons and cannot demonstrate

that any given project is worthwhile. Cost-benefit analysis bears an operational constraint in finding a way to reduce different kinds of costs and benefits in common monetary terms. An economic evaluation is then proposed and some indicators for measuring system's efficiency are discussed. Concepts like marginal cost, economies of scale, inflationary effects and capacity are reviewed through the analysis.

LIST OF SYMBOLS

A - amortization of input costs to the marginal cost of one search

A' - amortization of input costs to the rate of increase in marginal cost

dX - total production equation

E - elasticity of production

E_i - elasticity of production in relation to factor i.

$G(V_i)$ - Lagrange's minimum cost function

K - total cost elasticity

L - rate of income for the variable factor

P_i - price of factor i

S, S' - rate of amortization of input costs

V_1 - input effort factor

V_2 - search effort factor

X - production function (output volume)

$\bar{X}_i$ - average productivity of factor i

X'_i - marginal productivity of factor i

$\frac{X'_1}{X'_2}$ - rate of substitution between factor V_1 and V_2

W - volume of documents or references in the system

λ - marginal cost of factor V_2 at minimum cost condition

λ' - rate of increase in marginal cost

Π - total cost

Π' - marginal cost

$\frac{\Pi}{X}$ - average cost

$\frac{\Pi_i}{X}$ - average cost of input effort

CHAPTER I

PRESENTATION

1. INTRODUCTION

1.1 The need for a theoretical basis

Information science has been "suffering" for a long time now from the over-optimistic operational point of view that a measurement process can always be carried out independently of the availability of a theoretical framework. When borrowing a methodological approach from some other branch of science, e.g. economics, scientists must first agree, by common consent, on assumptions to be made prior to an actual experiment or testing a hypothesis. Tests of hypotheses are made in one language and our thinking is done in another. A theoretical language for the economic analysis of information systems is desirable and should come first, certainly earlier than definitions of concepts derived only from an operational testing.

In this research project an attempt is made to link theoretical concepts and operational concepts. We searched for a theoretical basis in the theory of production as accepted in the field of economics. An approach to the theory of production needs as a point of departure the definition of production in the technical sense. In using a wide definition production can be said to consist in any transforming process which can be directed by human beings; a transformation that is considered desirable by a certain group of people. The transformation called production does not necessarily change the potential qualities of things concerned in the process. It could be a MOVEMENT (in time or place) - transportation of goods or people, interlibrary loan services, etc... . It could be a SELECTION - of fruits in a crop, of words in a document, etc... . Or it could be a CONSERVATION - stock of goods, stock of books on shelves, document records on a magnetic tape file, etc... . A production process may use all three of these transforming processes and others using a specific technique.

In a theory of production a comparison is made among INPUT ELEMENTS and between them and OUPUT ELEMENTS and this can only be done using some form of VALUE JUDGEMENTS. As it has been pointed out by FRISCH (1):

" A characteristic feature of all scientific research is that it attempts to obtain results which are objective in the sense that they must be accepted by all those who have the necessary knowledge of problems and methods involved. In this respect scientific research differs from the work that involves drawing up rules of conduct for practical application and which in their most are expressed in political programmes ... . In the case of practical rules of conduct the question of issue is one of desirability and expediency - or belief in expediency - and this is based on a number of value judgement elements which must be considered in relation to the practical or political object in view and on which it would naturally be impossible to expect unanimous agreement. Every scientific analysis must operate with certain presupposition which - provided they constitute a system free from contradictions - it accepts without any attempts to further "proof" or justification... . In the last resort this choice of presuppositions contains some element - be it large or small - of value judgement. It is not until this evaluative point of departure is given, that the actual scientific analysis can commence."

The value judgements we started from in this work are explained in Chapter II in the section entitled "Theoretical approach to the study". For the purpose of this study an information system is viewed as a production system, the final product is defined as the information received by the user, which could be measured in terms of volume.

As has been stated before, production deals with input elements and the output that comes out from the system. In the case of production of goods, market prices provide the evaluation coefficient for measuring the system's efficiency. Production in the economic sense attempts to create a product which is more highly valued than the original input elements.

Considering an information service it is rather difficult - or sometimes impossible - to value the service in money terms. A market tradition does not exist for these types of services and one has to bear in mind the fact that the subjective value of money affects in a different way different persons receiving the same unit of information. Thus, even if an information service does not have a clear market price or value, it certainly has a COST associated to the input elements and the transforming process, what we call the OPERATIONAL CONDITIONS of the system.

The past cost studies of information services are financially and not economic-oriented according to economic concepts. Most of the so-called economic evaluations of information systems reflect only cost accounting. They show the flow of funds out of the organization and although it is essential for budget balancing at the end of a calendar year, it is not enough for decision making when the management is subject to objectives that have to be achieved with constrained resources.

Again, in the past studies, average cost is normally presented as a measure for cost forecasting and planning of new services. Nothing, or very little has been done to explore the behaviour of the incremental or marginal cost concept in information services. Output volume is normally accepted as the only variable influencing cost behaviour. Common sense and the results of the analysis presented later shows that cost is really one function of many variables, or operating conditions, of which output volume is only one.

The criteria for decision making, cost-effectiveness and cost-benefit analysis, do not seem sufficient in the actual context of documentary information systems. Cost-effectiveness is a valuable measure to compare projects. Cost-benefit could be the real indicator for decision making, comparing costs with benefits. It is well known, however, that the problems of assessing benefits and costs and reducing them to the same comparable unit of measurement are extremely difficult. To assess the transferring of information and its effects on the recipient is a very difficult if not impossible task.

The writer believes that economic analysis will give a better understanding of the system's environment and give some indicators for decision making in information science. The analysis seems to indicate the existence of unique evaluation indicators when it is applied to documentary information systems.

This work is divided in two parts:

1. The Cost Study

and

2. The Economic Evaluation

In the first part a cost study was made to identify variables influencing cost behaviour. In the second part, using the analysis of the theory of production, economic indicators were derived for the purpose of economic evaluation of information systems.

2. A BIBLIOGRAPHIC INTRODUCTION TO THE ECONOMICS OF INFORMATION

The literature on the economics of information appears in reviews of the literature under the headings of costing, cost-effectiveness and cost-benefit analysis. The literature of economics of information, as Price pointed out in 1974 (2), for papers on costing, has not been, to date, characterized by rationality or usefulness.

The literature on costing and economics of information had its first special chapter (3), in the Annual Review of Information Science and Technology, (ARIST), volume 7 in 1972. Before 1972 papers on costing appeared in ARIST under sections on systems design and evaluation. The term cost or costing does not even appear in the indexes of the first two ARIST volumes covering 1965 and 1966. The earliest 3 papers on costing reported in volume 1 of ARIST (4) are from 1955 (5), 1956 (6) and 1965 (7), but the first papers on costing seem to have been written about forty five years ago in 1936 (8) and 1937 (9).

The literature of the economics of information begin to be reviewed in 1972 when ARIST published its first section dedicated to costing, economics and other related studies in information systems and services. Almost all the important papers in the literature of the economics of information were reported in the ARIST reviews volume 7, 1972 (3), volume 8, 1973 (10), volume 9, 1974 (11), volume 11, 1976 (12) and volume 14, 1979 (13). From these five volumes, about 730 references are reported, which after discounting the overlapping, unpublished papers and citations among the 5 reviews indicated, produces a figure of just over 650 references. These 650 references deal not only with costing and the economics of information but with related subjects as well.

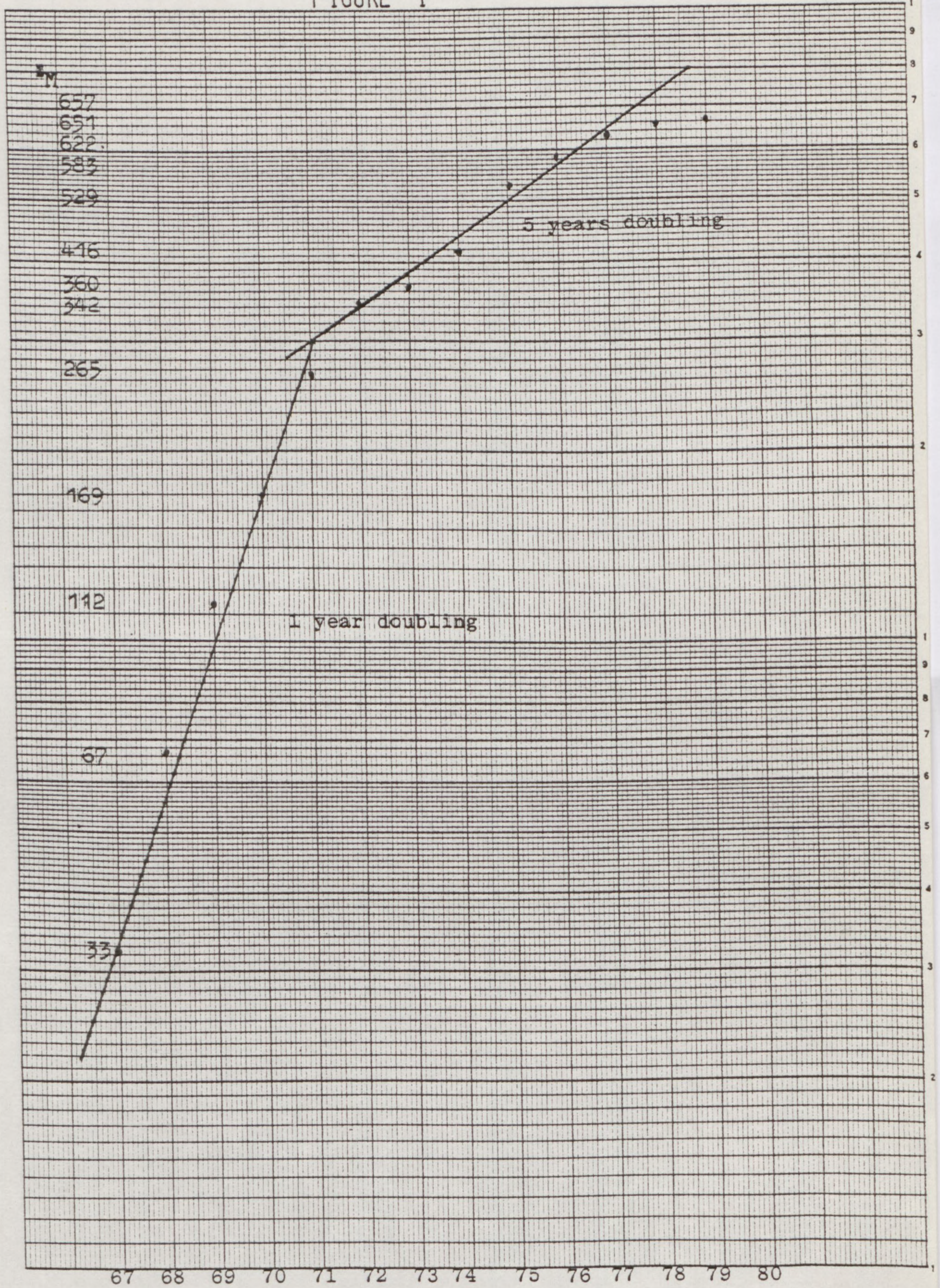
The subjects dealt with in these reviews are presented below, divided in 10 areas with a percentage indication of the number of papers in each area. Some papers overlapped more than one area and were placed under the heading which was dealt with in most detail. The literature is distributed by subject areas as follows:

SUBJECT	PERCENTAGE (650 = 100)
1. Costing	20
2. Cost-effectiveness	11
3. Cost-benefit	7
4. Budgeting	5
5. Economics of information	7
6. Information for economic analysis, economic theory, political economics	14
7. Operations research	7
8. Systems analysis and design	6
9. Statistics (collection of data)	4
10. Miscellaneous	19
	100

The papers on economics of information covers studies in resource allocation, demand forecasting, value of information and economic aspects of the whole system or one of its parts. In the miscellaneous category were placed papers dealing with management, marketing, pricing, funding, patent and copyright aspects, office equipment, etc...

The distribution of these papers by year are presented overleaf and in Figure I as a semi-log

FIGURE I



M
657
651
622.
583
529
416
360
342
265
169
112
67
33
5 years doubling
1 year doubling
67
68
69
70
71
72
73
74
75
76
77
78
79
80
year
Log 2 Cycles x mm, ½ and 1 cm
Chartwell Graph Data Ref. 5521

plot. (N.B. The initial very rapid doubling rate of 1 year followed by a further period of exponential growth with a still rapid doubling rate of 5 years . The suspected falling off in rate due funding changes was scarcely apparent by the end of the period.)

YEAR	NUMBER OF PAPERS	PERCENTAGE (653=100)	CUMULATIVE TOTAL OF PAPERS SINCE 1936
1967	29	4	33
1968	34	5	67
1969	45	7	112
1970	57	9	169
1971	96	15	265
1972	77	12	342
1973	18	3	360
1974	56	9	416
1975	113	17	529
1976	54	8	583
1977	39	6	622
1978	29	4	651
1979	6	1	657
	653	100	

The increase of papers in the economics of information and related subjects from 1969/70 seems to indicate the beginning of the colder economic climate of the seventies where scarce resources had to be divided among institutions which had now, more than ever, a need to explain to higher administration the costs of the services they were providing and the benefits for the community of users of these services.

In 1975 the British Library Research and Development Department strongly supported research in the field of economics of information (14). However, this support was withdrawn as pointed out in the Research Priorities of BLR&DD for 1979-1981 (15):

> "Research in the economics of information. This area, although extremely important, has consistently failed to give good value for staff effort. It is possible to secure good costing studies, but OECD and EEC have put substantial amounts of money into these and have somewhat restricted the scope for national studies. Cost-effectiveness and cost-benefit studies have proved difficult to design and several attempts to persuade economists to tackle them have so far failed,

though occasionally economists have given valuable help to specific projects, for example in library automation.

At present the Department believes that the best course of action is to sieze any opportunity to support a worthwhile project but not to devote much staff time to identifying possible projects and seeking possible homes for them."

At this point it is worthwhile to consider the five reviews from ARIST dealing specifically with costing and the economics of information.

The 1972 review, by J. H. Wilson Jr. was called "Cost Budgeting and Economics of Information Processing" (3) and it presents 180 references. The review states in its introduction "we are not concerned with marginal cost. The cost that information specialists are concerned with are working costs - total cost, unit cost, average cost, cost of a particular operation. These are the costs used in controlling operations and budgeting." Indeed, more than half of the references presented in the review deal with cost reporting and accounting and budgeting. The purpose of the review is said to "introduce some current approaches of cost to those who haven't had to deal much with them and to bring up to date those who are more acquainted with costs trends and controversies.... we will be concerned more with the techniques of costing and what cost and economic analysis can tell us, than with comparative costs."

The review is divided in five sections: cost reporting and accounting; cost-effectiveness analysis; planning programming and budgeting systems; the value of information; economics of information.

In the cost section some important studies are reported as Bourne's survey (16) and Price (17). However, under the same heading references are related to operational research (18),(19). Under the section on cost-effectiveness, cost is said to be "the determining criterion for system performance." It appears that a little misunderstanding is associated with the words effectiveness and efficiency that Lancaster tried to clarify (20). The treatment of cost for document transfer systems reached the textbook (21) and the application of computers to improve cost-effectiveness is analysed by Fasana (22).

A large number of references are given under the section in Budgeting which deals mainly with Planning Programming Budgeting Systems (PPBS). The review states that "the PPBS budget design should be helpful in conducting meaningful measurements of the total money cost of accomplishing the defined objective." Stitleman(23) lists several features that distinguish PPBS from traditional budgeting features. The section on the value of information deals with papers trying to establish a price for information (24) and cost-benefit analysis where papers in pure economic theory are presented (25). The difficult task of measuring benefits in information science is presented and many articles dealing with this problem are indicated, one of the most important being the Durham University Project (26). The review deals more with the theory of cost benefit analysis than with case studies. The section in economics of information is said to be "not directly pertinent to the review" and it states that "the first book devoted to the economics of information, and so far the only one, is The Production and Distribution of Knowledge in the United States" (27).

In 1973 ARIST presented in its volume 8 a review by M.D. Cooper, "The Economics of Information" with 144 references reported (10).

This review concentrates on a description of the various institutions that produce and disseminate information, the resources and constraints affecting production and distribution process and the tools and methodologies available for making resource allocation decisions. Among the tools that are reviewed for these purposes are: welfare economics, cost-benefit analysis, demand analysis, marketing research, cost analysis, cost-effectiveness analysis and operations research analysis.

A view of the economics of information is given by Lamberton (28): "The process by which information and knowledge is produced, diffused, stored and used". Two papers by Marschak (29), (30) analyse the rational decision making of an individual in terms of information that the individual needs to make a decision. He mathematically formulates the problem in terms of costs and delays involved in obtaining the necessary information. The model employed tries to analyse the cost and benefit of the information and its value.

Some statistical sources for the United States is given in the review to show a way in which information is created. A section on the communications industry is also very much concerned with United States statistics.

Under the information services section Machlup (27) is indicated as considering the economics of information science as part of the education industry.

The review presents then a section on resources and constraints of information services which considers "a limited set of resources and constraints such as availability of funds, taxation policies and legal structure". The literature presented is very much related to the United States environment and does not present any original paper on the economics of information. The next section deals with resource allocation and reviews some of the tools available that aid in resource allocation, decisions, etc... This section deals mainly with economic models (31), (32), (33), (34).

Under the heading of cost-benefit and cost-effectiveness analysis some papers are presented but again mainly related to case studies of the American experience (35), (36).

The cost section reviews papers related to "cost analysis in libraries, library automation, computer systems and mechanised information storage, retrieval and dissemination systems". The literature analysed is concerned with "a continuing process in which a data collection system is integrated with processing routines to generate periodic status reports on the financial condition of an organization or process (37). Some data collected for standard times of library operations were presented (38). A mathematical model for comparative cost analysis of information retrieval systems (39) and the overall economics of retrieval systems (40) were reported.

In 1974, ARIST volume 9, presented a review by M.A. Spence, "An Economist's View of Information" (11).

This review tries to relate information to market (as defined in economics) behaviour. The reviewer stresses that:

> "In general, the recent work reported here, demonstrates that informational problems cause market failures of various kinds. The aim of this reviewer has been to describe the types

of failures that are observed and to explain how they relate to information."

And the reviewer concludes:

> "As a result of recent work information has acquired a secure place in economic analysis" .... "In a typical consumer-goods market, information is transmitted by, or based on, salesman, advertising, price, brand names, word of the mouth, consumer action groups and the consumer's own experience. All these are aspects of the informational structure of many markets".

The 66 references presented are related to market economics and economic analysis and none to the problem of documentary information systems.

In 1976, ARIST published another review by M.A. Hindle and D. Raper called "The Economics of Information" (12) with 165 references listed.

It starts by giving a broad definition of economics of information as encompassing the whole of human decision making. The reviewers indicate that the literature on the period had studies concentrated in four areas: specialized information services, systems of libraries, the library as a system and collection and control within libraries.

The present review was divided into the following headings: Economic environment; Measures of costs and benefits; and Modelling. It is stated in the review that: "the literature even when claiming to study economic consequences of plans, very often comes up with a superficial analysis". The reviewer criticizes some papers for not describing properly the economic environment (41), (42), and (43).

The library as a system is said to be presented in a remarkable way by Hamburg et al.(44). In the methodological aspects the study of Flowerdew and Whitehead (45) is said to present economic methods for information studies.

In the section on cost and benefits some papers are indicated by their importance in cost studies. These are Schimpa (46), Adams and Werdel (47) and Vickers (48). Most libraries, it is said, will have made some attempts to cost their operation, however, a comprehensive guide to library costing is not still available.

A straightforward summary of costing methods is given by Ford (49) and Magson (50) presents an overview of cost benefit studies in university libraries.

Modelling is said by the authors to be a source of difficulty in communication between the librarian and the analyst, Bommer (51). The final part of the review is dedicated to mathematical modelling, (52), (53).

Assessing the whole review it does not seem to justify its name as "The economics of information".

With the name of "Cost Analysis of Information Systems and Services", by C.M. Mick, (13), ARIST presents its fifth review on the subject in 1979. The review presents 184 references. It is said to cover the literature from 1975 to 1979. However, most of the papers presented are from 1976 to 1978 with only 6 papers from 1979. There is a great deal of overlapping with previous reviews presented in ARIST.

A four level conceptual framework was used to approach the literature:

1. the function or service - an operation within an information organization;
2. the information organization itself;
3. the structure within which organization is located;
4. the aggregate level, which looks across similar types of organizations.

The literature, it was said by the author, failed to share the enthusiasm for this framework. Actually the whole review is quite confusing. Nearly half of the papers presented are related to costing, cost-effectiveness and cost-benefit analysis. Nevertheless, some new and important papers in the economics of information were presented by Braunstein (54), Cooper (55), Flowerdew et al. (56), Gold (57), King (58), Lancaster (59), Mason (60), Pratt (61), Price (2), Rowe (62), Vickers (63) and Zais (64).

To sum up, the approach to the literature in economics of information in the papers reviewed above, was found to be confusing and disappointing, mainly for two reasons:

1. they have been written by information workers with a lack of knowledge of economics;

or

2. they have been written by economists or

statisticians not used to the technology of information systems and specifically documentary information systems.

As a result of this two faults appear to exist:

I. misuse of economic concepts and methodology. For example, "economic efficiency" was found to mean "the efficiency of economizing" or "economic costs" being taken as "accounting costs";

II. rather complex mathematical model-building. These models are difficult for the manager of an information system or an information worker to understand and are not likely to be used in real life situations.

The points that have been overlooked in surveys applying the evaluation techniques of economics to information systems, are listed below under six headings:

1. Little or no effort has been made to assess the overall system, its relationship to its environment and with their components. The evaluation process lacks system thinking and as a result the interdependence of the

components have been overlooked; most of the "economic assessment" has been placed on the retrieval sub-system and most of the evaluation is cost-based, and then only in terms of a budget expenditure explanation. The writer believes that in real life all the stages in the process of transforming and transmitting information from generator to user should be considered in total evaluation. In an analysis of current awareness services, Bottle (65), suggested that economising on intellectual effort at the input stage of a (printed) information system, by the producer, normally requires extra intellectual effort to be expended in the output stage by the user.

Cost assessment does not give enough information for the purpose of optimal allocation of resources in a process-product oriented system. An appropriate measure of productivity would give management information for a rational allocation of resources in different sub-systems of the whole system. The present cost evaluation techniques are unable to provide information about cost inter-dependence for the whole system. If an increase in the coverage of the system has been decided, on the cost side this will not mean only an increase in cost of the coverage sub-system, but for the coding, storing, searching, sub-systems as well.

2. The treatment of costs on the economic evaluation process - to the best of the writer's knowledge it seems that most of the so called economic evaluations rely on accounting costs rather than on economic costs. Accounting costs reflect the flow of funds out of an organization and are essential to balance the budget at the end of the financial year. The economic cost (opportunity cost) is the measure of the value of resources that are being used for one activity and which cannot be allocated to another activity. It is the value of the foregone alternative. For management decision making the economic cost is far more relevant. However, most of the available literature accepts accounting costs as being suitable for decision making. The following quotation from J.H.R. Wilson Jr., (3), illustrates this point:

"We are not concerned as in classical economics with marginal costs ... The cost that information specialists are concerned with are working costs - total costs, unit costs, average costs, costs of particular operations. These are the costs used in controlling operations and in budgeting ...... "

By classical economics the author means he is not considering the economic cost but the financial accounting cost to explain a time period budget expenditure. Accounting costs are concerned with historic and "sunk" costs which, although needed for budgeting purpose, could be misleading if used for strategic planning and resource allocation decision making. The assumption that "the costs that information specialists are concerned with are working costs" is a very strong one. It is not difficult to forecast that in a world of increasingly scarce resources and rising prices the information specialist will be more and more concerned with "opportunity" costs and service pricing policies. In this way accounting costing is not a substitute for the economic marginal costing for pricing policies.

As long as information workers are concerned only with accounting costs of a service or department they will be given misleading information for decision making. It is worthwhile to quote an economist, K.E. Boulding (66):

> "Another profitable line of study lies in economic sociology, in the analysis of the way in which organizational structure affects the flow of information, hence affects his image of the future and his decision, even perhaps his value function. There is a great deal of evidence that almost all organizational structures tend to produce false images in the decision maker, and that the larger and more authoritarian the organization the better the chance its top decision makers will be operating in purely imaginary worlds. This is perhaps the most fundamental reason for supposing that there are ultimately diminishing returns to scale. In the most extreme case of this view, we can suppose that the whole structure and communication network of an organization determine the input to each role so completely that there

is virtually no freedom of decision at all, and that no matter what is the role occupant the decision will be much the same. The inference of this theory, of course, is that fools in high places will make just the same decisions as wise men and though there is something comforting in this one certainly hesitates to believe it too wholeheartedly."

3. The user evaluation of information systems - most of the evaluations of information services produced by these systems use only user satisfaction as the final system objective. User satisfaction is the real objective of any information system but the present techniques assume that the user is only an evaluator and never a consumer of information. The main effect of this is that operational efficiency has been the prime target of evaluation and economic evaluation has been overlooked. As long as the evaluation process is only based on user satisfaction the system will try to achieve operating efficiency disregarding the economic efficiency. Unfortunately in the long run, the final question to be answered by management is: "Is the system worthwhile?" and

not "Is the system operating efficiently?"

4. Short term and long term analysis - most of the present evaluation has been used in the short term in terms of costing and budget control. As far as the writer could observe the evaluators up to now fail to inform management of the long term implications of running systems. The implications of not having a methodology for long term forecasting is that managers of information systems will be working in the dark in respect of their planning horizon for strategic decisions.

5. Cost-benefit and cost-effectiveness analysis - there is a considerable part of the literature that uses economic techniques for cost-benefit and cost-effectiveness analysis. Again this analysis lacks a proper economic methodology and could be misleading. There is also some confusion between the two concepts and some of the cost-benefit studies are really cost-effectiveness studies. In its philosophical foundations cost-benefit analysis is a tool for helping decisions before undertaking a project or a policy. It claims to describe and quantify the social advantages and disadvantages of a project or a

policy in terms of common monetary unit. Applied to information systems the cost-benefit analysis tend to explain the existence of a service or a system rather than helping to decide between two services or systems. The benefits are taken to be for the individual (the user) rather than the social benefits and the unit of measurement tends to be the user satisfaction not quantified in the same monetary unit in which the costs are stated. It is worthwhile to quote here, A.D.J. Flowerdew and C.M.E. Whitehead, from the London School of Economics, in their report about cost-effectiveness and cost-benefit analysis in information science (45):

> " Despite much interesting work no really satisfactory cost-benefit study has yet been carried out."

6. The value of information -

In the present literature there is a lack of theoretical basis for trying to assess the value (at least in pricing terms) of a piece of information. This makes the analysis of the value of systems that are yielding information quite a difficult matter. It is understood that valuing a piece of information is quite a difficult matter because of the nature of the commodity and all the difficulties of measuring the unit of the commodity itself. Some practical research has been done in the field of information by asking the user how much he or his organization would be willing to pay for some specific information services. The willingness to pay in monetary terms is expected to be the value of information to the user and the average is determined for some community of users. This kind of analysis leads to two problems: first it is highly arbitrary to try and value the information from a subjective opinion of a user who has never been a consumer of that commodity. The user has normally utilized the system but not in a market situation as an economic consumer. Secondly it attempts to measure the service as a whole not considering its component parts.

It seems from the analysis of the literature and from the research in the area that because the economics of information systems is in its infancy the net result is a lack of a theoretical basis for the managers of information systems on which to make decisions. The published literature seems to indicate as well, that in the coming years there will be considerable application of economic techniques in the evaluation of information systems.

Independent literature search failed to locate additional major publications to those noted in the ARIST reviews. In view of their good coverage, they form a useful framework for the discussion of literature of the economics of information presented in preceding pages. Searchers for work using marginal cost concepts and the concepts of the theory of production applied to information systems were consistantly negative. Citation searches, however, located several recent references to Frisch's Theory of Production (1) though none of these were remotely concerned with information systems (cf.p.62). Thus it can be stated that no work has been done using the concept of marginal cost and the concepts of the theory of production for information systems evaluation and decision making purposes.

In the well known study by Flowerdew and Whitehead (45, pp 58/59), presented in 1974, a selection of projects were, however, recommended to fill apparent gaps in available and worthwhile research:

> "... data collection on both cost and uses of the service. These data must then be analysed to obtain estimates of long and short run average

and MARGINAL COST*.... Full analysis should provide evidence to answer: 1) Are there economies or diseconomies of scale in the production of a particular library service (i.e., as output of the service expands do unit cost increase or decrease); 2) what is the optimal scale of output for a certain library service and what level of output should changes in methods of production take place."

A very similar approach was, however, presented independently by the author of this thesis in his research proposal submitted in mid-1973 and the further development of the thesis that will follow.

It is worthwhile to point out also, that in a symposium on economics of information held in Germany in May 1981, no work was reported as using the concepts of marginal cost and production theory as presented in this thesis. (64-A)

* This author's emphasis

CHAPTER II

THE COST STUDY

1. Cost Analysis and Economic Analysis

Studies carried out to analyse cost behaviour in information services are somewhat recent and normally arise as a derivative of cost-effectiveness and cost-benefit analysis of a particular service. Few systematic studies were found and none of these were based on a specific economic theory adapted for the economic analysis of systems for manipulating information.

Numerous studies on average and total cost were found but none made any effort to analyse the marginal cost in information systems. This is especially noteworthy in view of the importance of marginal cost to the general price theory and its even greater importance to the internal management of the system. Studies of this type have most probably been made by private firms but not found their way into print because of the confidential character of the data.

Average cost is defined as the cost per unit of output, i.e. the total cost of the whole period divided by the number of units of service produced during that period. Marginal cost (also called incremental cost) is defined as the addition to the total cost caused by the production of one additional unit of the product or service, i.e., that particular increment in total cost which is associated with a unit increase in output.

The time period may be defined as a time span too brief to permit alteration in the scale or character of the fixed equipment and technology employed. For the purpose of this study accounting periods may vary according to services as in retrospective search services or SDI services.

An understanding of the behaviour of short period average cost may be useful for several reasons:

1. It will aid in establishing cost standards which can be used for controlling costs;
2. It will help management to institute programs of cost reduction based upon more accurate knowledge of the causes underlying cost behaviour;
3. It will assist in computing estimates of costs under the same conditions for future operations of the system.

Even more important may be the utilization in decision making process of a knowledge of marginal cost behaviour. Most short term managerial decisions should be made by balancing the additional cost caused by a suggested policy against the consequent additional revenue, or at least the additional benefit, for services that are not charged. As a general rule this will apply to any type of decisions such as the introduction of a new service, a new transformation process or a new marketing policy or changes in other operational conditions which are typical of information services.

More and more attention has been directed to the importance of marginal cost as a measure more indicative for economic analysis of productive units, but the problem has invoked little statistical investigation. Nevertheless, it is becoming increasingly recognized that costs compiled by routine traditional accounting procedures has little value as a guide to short term decisions and therefore little significance in determining price of a service. Orthodox accounting methods assume that costs, once they have been reduced to a monetary unit they are homogeneous in behaviour and equal in importance. Accounting costs tell little about the effect of changing operational conditions upon average costs. Most of the cost studies in information services using collected real data apply the concept of average costs, assuming that the volume of output is the only variable influencing cost behaviour. Average costs derived from systems using different operational conditions could not be generalised for decision making, planning and forecasting. If systems are using different factors of production and in a different factor diagram (the balance between fixed and variable factors of production) any generalisation based on average costs could be dangerously misleading. The concept of average (or unit) costs is based on the rate of output as the only variable affecting cost behaviour. On the contrary, cost behaviour is affected by several variables that will act alone or, more likely, that will be interrelated.

2. Operational Conditions: Factors of Production

When undertaking a production analysis to study cost and other economic coefficients (1) one must therefore select certain factors whose effect on production and costs one wishes to consider more closely. We call these "specified factors of production" and the others "implied factors of production". The distinction between specified and implied factors will have a certain connection with the question of whether the factors of production can vary or not, depending on some period of time and what specific technology is used.

In certain cases a production process necessitates, for the purpose of achieving its objectives, the utilization of large facilities which in a fairly precise manner defines the CAPACITY of the particular concern. Moreover this CAPACITY cannot be altered except at great expense and after a considerable period of new constructional work. In such cases it is obvious that it may be of interest to study how the quantity of the product, its quality and cost vary if the factors determining CAPACITY remain constant while other factors of production may vary. The latter factors are called variable and the former are referred as being fixed. The manner in which they combine constitute the operational conditions of the system of production.

This kind of analysis has been neglected in cost studies on information services. Some cost analyses mention or divide costs into variable and fixed but the analysis does not then go any further into the characteristics of each factor nor their relationship or interdependence.

The economic concept of CAPACITY has also been neglected in previous studies or, more commonly, has not even been considered. In an industrial production process, the use of large machines, containers, physical location and transport facilities, define in a precise manner the TECHNICAL PRODUCTION CAPACITY of the particular concern.

Production capacity, in an information system environment, has never been defined or studied, even considering that it might represent an important variable in the analysis of the whole process of production. It is from the balance of the variable parameters upon factors which will determine capacity that the greater part of the present analysis will proceed. Factors which determine capacity are fixed in the short-run.

The writer believes that the concept of capacity will vary for different information systems according to the service or services they provide. For a library system, for example, capacity parameters may include the physical location, the fixed equipment and the size of the collection. For retrospective search services the "Input volume (size of the data base) and equipment facilities might define the system capacity. For SDI services the "Input rate" (number of items added in each search period) and equipment capabilities may also define capacity. The capacity so defined is the maximum capacity for the system and is determined by a physical limitation.

If this reasoning could be accepted, it is a presumption that information systems are, in most cases, operating in a state of undercapacity or, one of always having "idle capacity". It is, also, a presumption that for some systems (library and retrospective search systems) the idleness is increasing annually because of operational requirements, and the known propensity of users to concentrate demand on the more recent material. In this sense, the concept of capacity is an important investigation line to be pursued, as it will strongly modify the concept of "economies of scale" when applied to systems providing information services.

The factors or conditions which determine capacity will have to be combined with some variable factors before the service becomes available.

In information systems we have basically three factors of production which perform the transforming process. They are named for the purpose of this analysis:

1. Setting up or initial effort
2. Input effort
3. Output effort or search effort

"Setting up effort" is meant to comprise all the work required to start a new service or in any further development of existing services. "Input effort" comprises location, selection, any form of compression (e.g. abstracting), classification, and storage of the raw material (primary literature) or its representation (e.g. references), including intellectual and administrative work, equipment and materials and the work involved in dissemination.

In terms of cost and capacity these three basic factors of production will be classified as follows:

FACTOR	TYPE OF COST
1. Setting up effort	fixed, inescapable after they have been incurred, determine system's capacity
2. Input effort	fixed, inescapable after they have been incurred, increase system's capacity up to physical limit.
3. Output effort	variable, proportional to units of service until the capacity of the system has been reached

3. <u>Operational Conditions and Cost Behaviour</u> - variables related to Cost

In the work carried out to identify variables affecting cost behaviour,data from two published surveys were used:

E. Peeters, "Couts du traitment automatique de l'information documentaire"
(Costs of mechanized documentary information) (67)

P. Vickers, "Cost of mechanized information systems" (48)

The two surveys present cost data for mechanized information systems. The Peeters study also presents some times for processing the services. Both sets of data were presented for one accounting period only. No historical series of data is available up till now, thus a real study of marginal cost could not be performed. However the methodology to study marginal cost is presented in the next chapter. The first stage of this project suggests that cost is not only a function of output volume. Costs in information systems suffer the influence of "combined conditions". The variables affecting this combination were investigated as much as the cost data available permitted.

The analysis was made in two stages:

I - for systems providing retrospective search services;

II - for systems providing SDI services.

The availability of real data on costs for information services made the objectives of this study limited to

a) exploration of a methodology;

b) development of a practical procedure;

c) investigation of cost behaviour for the purpose of:

1. determining cost standards;
2. improving cost forecasts;
3. provisional indications for determining marginal costs;
4. cost indications for a possible pricing policy.

In the cost analysis variables affecting costs were examined. The closeness of the relationship between <u>cost</u> and the parameters which normally affect information systems was considered. Two kinds of measures were used:

a) the index of simple and multiple correlation;

b) the index of simple and multiple determination.

The "index of correlation" measures the closeness of the relationship between cost and variables that could be affecting it.

The "index of determination" is the square of the index of correlation. It states the proportion of the variance in cost which is "accounted for" by the variables affecting it. It may be said to measure the percentage into which the variance in cost is determined the variables affecting it.

Most of the statistical methodology was taken from M. Ezekiel's standard textbook (68).

3.1 <u>The analysis of data presented in Peeters's survey</u> -

As indicated in the survey 44 centres providing information services were contacted but only 13 sets of data could be used for this cost study. Average cost is presented as unit cost in the survey.

The cost data were presented in Belgian francs (with no indication of the date or where in Europe the centres were located). However, the survey presents data on times for various operations, for the services provided by the centres. It was then possible to study the costs presented using data on times (assuming these to be in constant proportion to costs).

In the original study only one variable, volume of output, was related to cost behaviour and one of the Peeters's main conclusions was that "the cost of a search is a decreasing function of the number of searches per year". Other factors that could affect cost were examined by the writer using the same set of data. These factors were:

i) Input effort - measured in terms of average time spent for each unit of input into the system;

ii) Search effort - measured in terms of average time spent in one search;

iii) Input rate - number of documents added each year;

iv) Volume of output - number of searches per year.

From tables 10 and 13 of Peeters's study (Appendix 1), the following table for 8 different information systems was constructed:

TABLE 1.

Number of documents added each year (input rate)	Number of searches per year (output volume)	Input effort (in minutes for each doc.) (a,b,c)	Search effort (in minutes) (a,b,d)	System No.
27,000	1,600	78.40	41.00	1
10,000	375	56.16	240,00	3
2,000	600	11.55	22.00	4
26,000	100	12.90	150.00	6
30,000	200	57.00	492.00	7
30,000	10,000	1.00	12.00	8
3,000	50	20.00	14.40	9
500	60	72.00	1,000.00	11

The letters a, b, c, and d, indicated in Table 1 are explained as follows:

a) average data;

b) time of personnel effort only; (found to be 67% of the total effort)

c) input effort includes selection abstracting, indexing and processing;

d) time in minutes to produce one search.

The first conclusion to be drawn from Table 1 is that the considerable differences in unit time for input effort and search effort seem to indicate that very different techniques are being used in each system. This indicates that average cost, or unit cost, derived from the survey cannot be generalized to give:

Cost standards,
cost forecasts
or
pricing policies.

If <u>search effort in minutes</u> is taken as an indication of the variable cost per search, it is possible to examine some conditions affecting costs. The measures, for <u>search effort</u> as a dependent variable were found to be:

independent variable	index of correlation (simple correlation)	index of determination
1. input effort	0.55	0.30
2. input rate	-0.25	0.06
(excluding system 11)	0.35	0.12
3. volume of output	-0.32	0.12
(excluding systems 8 and 11)	-0.11	0.01
4. input effort AND input rate	0.56	0.36

From the correlation data we may see that the most significant variable related to search effort (cost per search) is input effort. For this the positive index of correlation amounts 0.55 and the independent variable seems to explain in 30% the behaviour of the dependent variable as indicated by the index of determination. The second most important variable is the input rate if system 11 (search effort of 1,000 minutes per search) is excluded. These two variables are not interrelated, as the multiple correlation index does not increase more than 0.01 for the addition of the variable input rate.

The fact must be pointed out that the size of the sample and the correlation indexes are such very low figures which do not permit final conclusions. However, there is no indication or evidence, from this set of data, that cost is a decreasing function of volume of output (number of searches per year) as pointed out in Peeters's conclusions. If and only if, the fixed and inescapable cost of the fixed input effort is considered, is that conclusion valid.

If the variable cost per search could be examined it would probably be an increasing function of the input effort and the rate of input into the system (Peeters's data, however, did not permit such an examination).

3.2 <u>Vickers's data for retrospective search</u> (48)

The same approach was used on the data presented in the Vickers's survey for systems providing retrospective search services. Search effort, size of the data base and output volume were examined as variables likely to influence costs.

The unit of measurement for cost was assumed to be the variable cost per search as indicated in the original table (reproduced in Appendix 2 of this report). Input effort could not be analysed with this set of data because some systems were using "in house" data bases while others were just processing a purchased data base.

From Table 14 and Appendix VI of Vickers's study the table below can be derived for 8 different systems:

TABLE 2

Vickers's data on retrospective search

Size of the file searched (no.of items)	Number of searches per year	Variable cost per search (U.S. $)**	Search effort* per year (U.S. $)	System No.
160,000	1,000	33.60	27,100	1
100,000	200	36.75	7,628	9A
516,000	1,600	22.30	35.084	11
22,000	150	4.60	712	12
40,000	3,600	9.20	31,224	13
23,000	1,200	10.50	10,106	14
40,000	2,625	3.30	6,563	18
1,000,000	1,800	133.70	43,045	19

* Cost of search effort comprising: search formulation costs, computer processing costs, output printing costs, output checking, reproduction costs, mailing and distribution costs.

** In 1971 $/sterling exchange rates were reasonably stable at $2.40 to £1.

The correlation indexes for the dependent variable (variable cost per search) with the independent variables were found to be:

	Independent variable	Index of correlation (simple correlation)	Index of determination
1.	number of searches per year (output volume)	-0.21	0.04
2.	volume of input (size of the file)	0.91	0.83
3.	search effort	0.64	0.40

From this set of data it was found, again, that the volume of output is only weakly related to cost. There is still no evidence that costs are a decreasing function of volume of output. However, there is some indication that incremental costs is an increasing function of some operational conditions as:

1) Input volume (size of the data base)
2) Search effort

3.3 Analysis of Vickers's data on costs for SDI systems

The study of the conditions affecting cost behaviour in SDI services was made using data extracted from the Vickers's survey and the data presented for 11 centres as indicated in Appendix 3 of this work. From Vickers's table, the table presented in our Appendix 4 was constructed, where the data were rearranged to fit our needs.

We tried to identify operational conditions affecting cost through simple and multiple correlation testing. The variable cost was used and the fixed cost of data base construction or purchase was considered inescapable after having been incurred and thus not affecting short-term decisions. All variables used in the correlation process were derived from Vickers's data and explained in Appendix 4 of this thesis.

Six dependent variables were studied in relation to the independent factors examined. Listed below are the dependent and independent variables considered in our study:

I) <u>Dependent variables related to cost</u>

Variable cost per year
Variable cost per profile per year
Cost per profile per run

Average number of output (items) per run

The independent factors (variables) which may form the operational conditions of the system were:

II) <u>Independent variables that could affect costs</u>

Number of searches per year
Number of records per year
Number of runs per year
Number of search terms per profile
Number of items of output per run
Number of records per run
File size per search
Number of profiles per search
Volume of output (items) per year
Computer processing per run
Profile maintenance per run
Number of search terms per run

In Appendix 5 of this thesis the correlation and determination indexes for these variables are given, and thus their influence on costs can be assessed. An interesting indication from that table is that the time interval of one year gives poor indications of cost behaviour for SDI services. The important time interval seems to be the period of time when the variable elements act on the fixed element (rate of input). Thus the analysis was carried out taking cost per run as the short term variable cost.

The variables affecting cost more strongly than the average were found to be: (Simple correlation)

Number of profiles per search

Volume of output per search

Computer processing per run

Profile maintenance per run

Number of runs per year.

Stronger correlations were found when some variables were interrelated acting to explain cost behaviour: (Multiple correlation)

Number of profiles per search

AND

Number of runs per year

Computer processing per run

AND

Profile maintenance per run

Number of records per run

AND

Number of search terms per run

Number of search terms per run

AND

Volume of output per run

Profile maintenance per run

AND

Number of search terms per run

Computer processing per run

AND

Number of records per run

The correlations with number of output (items) per run as an independent variable show some factors that could increase the volume of output (items) per run and thus theoretically decrease the cost per item of output. These variables are shown in Appendix 5 of this thesis and it is interesting to note that some of these variables are directly related to cost in an increasing manner. If they will increase the volume of output (items)* they will not push costs down but they certainly will increase the cost per search.

*NB: By "items" is meant the number of references produced.

CHAPTER III

ECONOMIC EVALUATION

1. <u>Theoretical approach for the study</u>

Most of the theoretical approach for the study was based on the Ragnar Frisch "Theory of Production" (1). The concepts were taken from: PART ONE - Basic Concepts of Production; PART TWO, Chapter 5 - Various Methods of Describing a Continuous Production Law, Chapter 6 - The Technical Optimum Law when Considering Partial Variations of a Factor or a Group of Factors and Chapter 10 - Economic Adjustment to Fixed Prices.

The main objective of this study was to try to formulate a production function for information systems, aiming towards cost minimization and product maximization under the conditions of a continuous variable factor, search effort, V_2, and input effort, V_1, a factor with characteristics of indivisibility, but not a limitation factor. They are not independent factors and input effort, V_1, affects the adjustment of the variable factor, search effort, V_2.

The production function would be then:

$$X = f(V_1 V_2)$$

where:

X = quantity of output

V_1 = input effort

V_2 = search effort

The author is aware of certain developments in the theory of production since it was formulated in 1965 in Frisch version. Most of the new theoretical approaches are based on price uncertainty and the production flexibility to it, i.e. the fact that all decisions are made before the market price of the commodity or service being produced is known.

We dare to say that for information systems the price in the market is not as a strong variable as the behaviour of the demand for the information service provided by the system. However, for the sake of clarity we assume that in our production function no account is taken of uncertainty, as defined in Turnovsky (69), in the production of information services. All the production decisions for a given period are made before the selling price for that period is known, and that once those decisions are made they are irrevocable.

It is important to stress also, that all the Frisch concepts used in the present analysis are valid to date, and that any new development on the theory of production, apart from uncertainty, were made to fit specific applications to a specific market or product. Some recent examples where Frisch's theory of production has been cited are references (70), (71), (72) and (73).

Some definitions and assumptions connecting the theory of production to information systems are needed. These are the "value judgements" from which the analysis of this chapter will start:

1. TECHNICAL PRODUCTION -
   technical production means any transformation process which can be effected by human beings. The transformation process indicates that goods or services which enter the process lose identity in it, ceasing to exist in their original form, while other things emerge from the process. The first are called input elements (or factors of production) and the latter are referred as output (or final product). The transformation process, in the technical sense, need not alter the actual material qualities of things concerned, but could merely be a movement, a selection or a conservation. A production process, in the technical sense,

need not be necessary to create VALUE or USE. If a product (or information) becomes valueless owing to the state of the market (or user judgement) the process that produced it is still a production in the technical sense of the word. In a production process there exists input elements, output and a technical or quasi-technical relationship between the two. These input elements will be either fixed or variable. Information systems which perform the transformation process of selecting acquiring, indexing, storing and disseminating information are in our view production units. They have input elements such as books, periodicals, etc... manpower and some sort of equipment. They have a transforming process according to some very specific technique and the final product does lose its identity in the process. Certainly these kinds of systems exhibit a process of selection, movement and conservation.

In the analysis the quality of the final product is considered constant. If the information received by the final user is completely non-relevant it has a cost for the system which producesit just as much as relevant information has.

2. SINGLE-WARE PRODUCTION -

a single uniform product is provided OR different services could be reduced to a single unit of measurement OR the analysis has to be made for one service at each time.

3. TECHNICAL MEASURABILITY -

the quantity of output and the quantity of input elements used in the process can be measured in some appropriate unit. The information service provided by the system has to be reduced to a defined unit, i.e., <u>one search</u>, regardless the number of references in each search.

4. CONSTANT TECHNIQUE OF PRODUCTION -

the transformation process is carried out under the same technique for all the output yielded by the system, i.e., the operational conditions remains the same for the period under observation.

5. SHORT TERM -

is defined as the length of time when a

certain factor of production, its price and the technique of production are held constant.

6. LONG TERM -

the length of time when all factors of production, the technique of production and prices may change.

7. OPERATIONAL CONDITIONS -

they are formed by fixed and variable factors of production which adjust together under a specified transforming process.

The analysis performed in this chapter and the next chapter is made considering production in the short term.

The use of this kind if analysis should enable the study input elements in relation to each other and to output. A "technical coefficient of production" could be devised for the input elements which form the operational conditions of a particular system. Measures of productivity for these elements could be defined. The system manager knowing the technical relation and the productivity of each input element and its costs (or the availability of his resources) could efficiently allocate resources, plan changes in the services and if necessary formulate a pricing policy.

However, it should be pointed out that the difficulties of calculating the cost of a particular input element per unit of output for information services is a difficult task. Nevertheless, the study of these input elements in the way proposed give, at least, an approximate indication of the behaviour of these "technical coefficients", and in which manner their variation could modify the cost structure of the system.

The theoretical approach presents the idea of marginal or incremental costs, i.e., the cost of one unit more of the particular service being provided. It differs from the concept of "unit costs", which has constituted a major part of past studies and which brings with it the idea of average costs.

2. Economic analysis and information systems

The cost study is indispensable to construct a framework of the evaluation environment. But as it has been discussed several variables are related to cost. The "Unit cost" measure, based on average cost, can only give misleading information for decisions as the writer tried to demonstrate in the previous chapter.

Single measures of "economic efficiency" are needed for the decision process. These measures are suggested in this chapter. Not only the measures, coefficients or indicators are important, but the whole process of analysis is a new way of looking at information systems.

In a published note (74) D.J. Urquhart made some remarks about economic research in the information field. Quoting part of his note:

> "These proposals arise from a source, which believes implicitly in the "economic man" and the concept that demand creates supply. But the absence of any useful results from previous attempts at the economic research into information transfer suggests that the basic tests of the economist

do not apply in this field. The position appears to be that the "information man" is substantially different from the "economic man". Undoubtedly he lives in a world where supply can create demand."

For a first comment on his note it may be said that not enough real economic research has been done in information transfer systems to suggest the absence of useful results, due not to researchers trying and failing to get useful results, but to the lack of appropriate work being done. Here it could be pointed out that there has been a misunderstanding of the methodology of analysis where cost analysis alone is taken to represent a full economic analysis. Secondly, the "economic man" may be different from the "information man" on the consumer side. The information consumer has not historically lived in a market situation. Thus he does not need to behave as rationally as the "economic man" when choosing his options for gathering information.

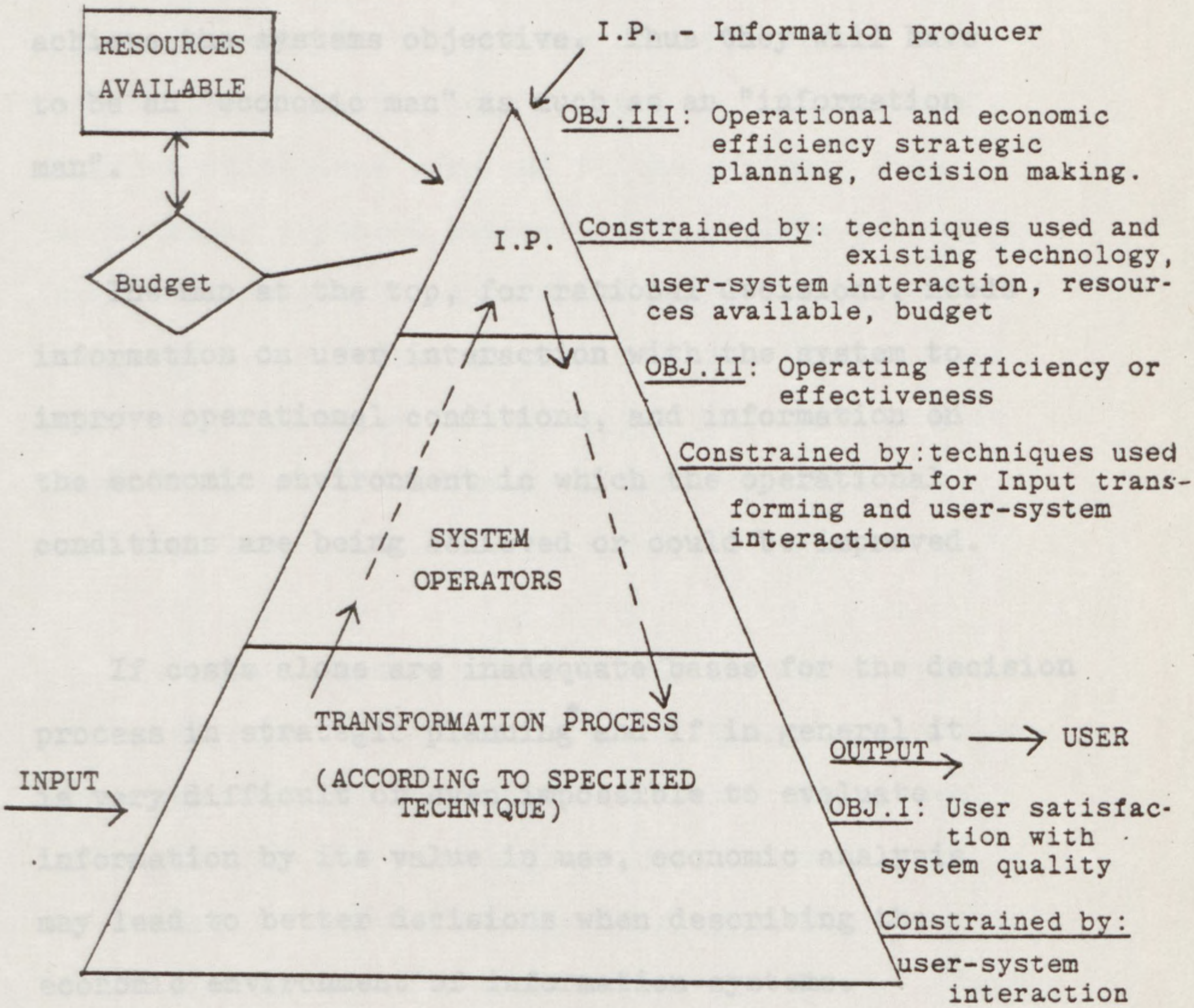
The information production man, however, has to be as rational as the "economic man" when allocating available resources and understanding the economic factors that may be affecting the operational efficiency of his information system. He needs to be even more rational than "economic man" as he lives not only in a world where supply can create demand, but also in his environment, supply could be constrained by demand.

Economic analysis will have many ways of helping the information producer man. At the moment, however, it seems it could be most effectively used in the process of decision making. Many decisions about an existing information system have been made until now on the basis of cost analysis only. We may use a model like a pyramid to illustrate that for an information system there are three levels of objectives as in any productive unit. Decisions will have to be made at each level and they are not only bound to cost constraints. These decisions will certainly be influenced by operational and economic factors. Operational efficiency has a well defined and accepted methodology in the information field. This is not the same on the economic side. There is a lack of methodology and indicators for decisions on economic efficiency. The information producer will need to know more about the economic nature of all the factors affecting his production unit.

The objective/decision pyramid is illustrated in Figure II.

FIGURE II

The Objective-Constrain Pyramid



It demonstrates the idea that there are a number of persons engaged in the whole process to achieve the systems objective. Few persons in the top level will be called "information producer man". They will have to combine economic and operational efficiency to achieve the systems objective. Thus they will have to be an "economic man" as much as an "information man".

The man at the top, for rational decisions, needs information on user interaction with the system to improve operational conditions, and information on the economic environment in which the operational conditions are being achieved or could be improved.

If costs alone are inadequate bases for the decision process in strategic planning* and if in general it is very difficult or even impossible to evaluate information by its value in use, economic analysis may lead to better decisions when describing the economic environment of information systems.

An example of how this analysis may be used is given with the data and conditions taken from reference (75) and summarized in appendix 6 and 7.

It assumes a manual system with input rates of

*By strategic planning is meant high level decisions on system development, changes in technique, marketing, etc....

2,000 documents a year - system 1 (S1) - in one case and 10,000 documents a year - system 2 (S2) - in another case, the same technique being used in both systems over a five year period.

In the example the average cost per search for both systems are inversely related to the volume of searches which have been put to the system. This is obviously expected because if the volume of output (searches) increases, some fixed costs are spread over more units. The rational decision in this case would be to increase the volume of output as much as possible to use the effects of economies of scale over the fixed cost.

But this information based only on the analysis of the average cost, does not give enough information about the economic environment in which the system is operating. Nor does it help decision making if the volume of output is a fixed or quasi-fixed variable in the system, i.e., how explicit would be the information that search costs decrease if the number of searches increases when the system is operating with a constant fixed demand of 100 searches a year.

If average costs are the only information to back decisions and planning for the future the probability of wrong decisions would be considerable. That is where a procedure for economic analysis of information system could help.

To begin with the economic considerations, one will have to know that "setting up costs" is a decision variable only in the year 0. As long as a decision is made to start the service, setting up costs are bygones and bygones are bygones forever in the economic world. Any economic decision of how the system is operating in year 1 or 2 will not take into account setting up costs incurred in year 0.

The next decision would be about the INPUT RATE*, i.e., the number of documents fed into the system during a specified period of time. This decision has much to do with the quality of the service provided and users' need of information.

A higher input rate will mean a more comprehensive system and the probability of better quality of output. However, as long as a decision has been made on the input rate this will represent a fixed factor for the production of the service. It does not limit capacity as in the industrial sense but it varies

* INPUT RATE in our example is cumulative over a time period into INPUT VOLUME.

only in significant amounts in fixed or quasi-fixed proportions. It can be left idle like a big machine in a production line that is not properly (or economically) used.

In both systems considered in this example the only variable factor is SEARCH EFFORT, i.e., the amount of time for producing one unit of output (regardless the number of references found in each search). Thus the production factors of System 1 and System 2 could be summarised as:

Production factor	Characteristic	Type of cost
setting up effort	fixed	fixed inescapable after year 0
annual materials	fixed	fixed inescapable once incurred
input effort	fixed	fixed inescapable once incurred
search effort	variable	variable in units of one search

In a working system, if we abandon setting up costs and aggregate annual materials costs in the input effort cost we will have our production subject to two factors INPUT EFFORT (V_1) and SEARCH EFFORT (V_2).

If X is the amount of output from the system (number of searches) it then will be a function of

V_1 and V_2:

$$X = x(V_1, V_2)$$

and the total cost of production would be:

$$\Pi = P_1 V_1 + P_2 V_2$$
$$\Pi = C + P_2 V_2$$

where C is a constant corresponding to the cost of the fixed rate of input and $P_2 V_2$ the cost of the variable factor of production.

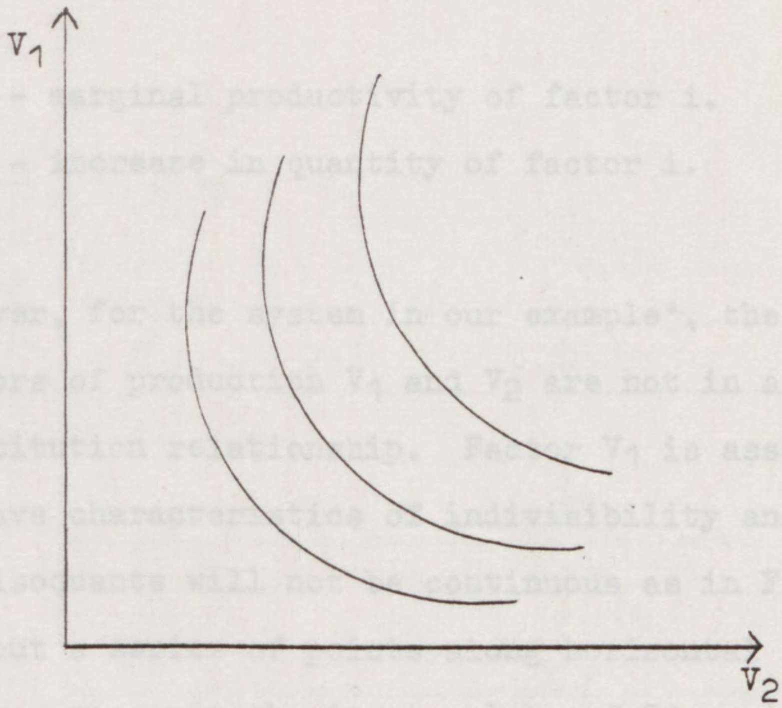
The next information the decision maker ought to have would be about the technical relationship of the production factors utilised by the system. Thus the economic concept of "substitution of production factors" is not applicable in this environment. Input effort and search effort are not replaceable for each other in order to maintain or increase the amount of output. In other words the number of items or documents which have been put into the system (input effort, V_1) bears no relationship to the productivity of the whole system*. The rate of input

* No consideration is made here as to QUALITY of output. Productivity of a production factor is considered in the technical sense as the rate between increase of output quantity and increase of the factor quantity. The output is considered to be homogeneous in the technical production sense.

may and probably will influence the productivity of system, but it alone will not have any influence in the volume of output. One cannot replace search effort by input effort and still have the same amount of output. That is where cost analysis alone could provide misleading information about the economic performance of the system. Average cost analysis will show increasing returns with increasing scale of production, not because the system is performing with higher efficiency but mainly due to spreading the investment made through input costs.

The concept of normal from the economic theory - equal product curves - again is not applicable in this type of system. If the factors we are considering were divisible and substitutable we would have curves shaped towards the origin as in Figure III overleaf:

FIGURE III



and the substitution ratio would be

$$\frac{X_1'}{X_2'} = - \frac{dV_2}{dV_1}$$

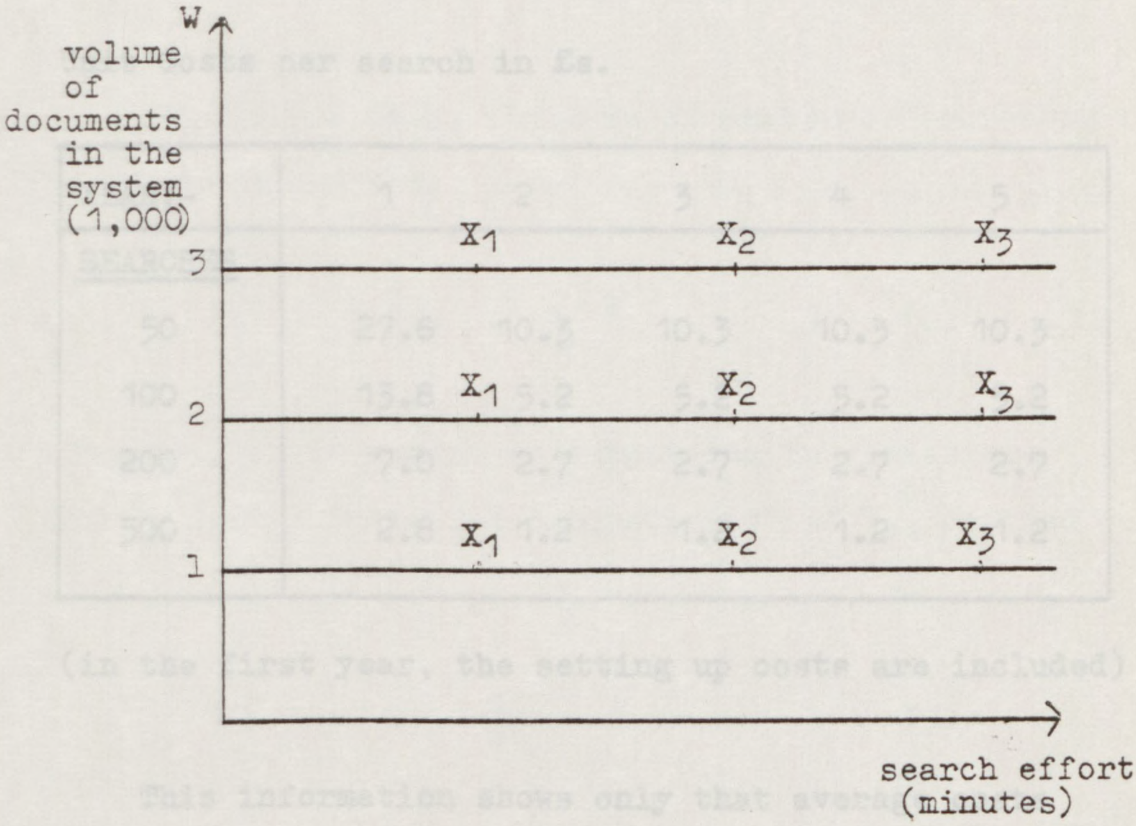
X_i' - marginal productivity of factor i.

dV_i - increase in quantity of factor i.

However, for the system in our example*, the factors of production V_1 and V_2 are not in a substitution relationship. Factor V_1 is assumed to have characteristics of indivisibility and so the isoquants will not be continuous as in Figure III but a series of points along horizontal lines which represents the input volume of S1 as in Figure IV overleaf:

* The analysis has been using systems indicated in Appendices 6 and 7. This is an in house system that produces its own data base and searches it. For a data base processor the same analysis could be used. For a data producer only the methodology could be used but the implications would be different.

FIGURE IV


W
volume of documents in the system (1,000)
3
2
1
X1
X2
X3
X1
X2
X3
X1
X2
X3
search effort (minutes)

The analysis of system 1 (S1) with an input rate of 2,000 documents per year over 5 years gives in the first instance the unit cost of a search as indicated in Table III below:

Table III

Unit Costs per search in £s.

YEAR:-	1	2	3	4	5
SEARCHES					
50	27.6	10.3	10.3	10.3	10.3
100	13.8	5.2	5.2	5.2	5.2
200	7.0	2.7	2.7	2.7	2.7
500	2.8	1.2	1.2	1.2	1.2

(in the first year, the setting up costs are included)

This information shows only that average costs are inversely related to the number of searches. Costs presented in this way show the existence of "economies of scale" but does not indicate the reason for the increasing return.

If we accept that search production is related to two production factors: input effort, V_1 and output effort, V_2 (search effort), search production is a function of V_1 and V_2 as:

$$X = x(V_1, V_2) \qquad (1)$$

Factor V_1 is accepted as fixed indivisible input, that being essential to production does not limit capacity or influence the quantity of output.

Production then, in terms of number of searches, is a function of V_2:

$$X = 0.5\, V_2 \; * \qquad (2)$$

The rate of increment in output due to variations in V_2 is the "marginal productivity" of V_2, defined by:

$$X' = \frac{dX}{dV_2} = 0.5 \qquad (3)$$

The rate of input for factor V_2 is

$$V_2 = 2.X \qquad (4)$$

and its average productivity

$$\bar{X} = \frac{X}{V_2} = 0.5 \qquad (5)$$

* V_2 is search effort in minutes and has the numerical value of 0.5 under the conditions set out in Appendix 6..

The expression for the total product is:

$$dX = \frac{\partial X}{\partial V_1} \cdot dV_1 + \frac{\partial X}{\partial V_2} \cdot dV_2 \qquad (6)$$

if

$$\frac{\partial X}{\partial V_1} = 0$$

then

$$dX = \frac{\partial X}{\partial V_2} \cdot dV_2 \qquad (7)$$

Equation (7) indicates that product increment is only related to search effort in this particular case.

The "elasticity of production" relative to factor V_2 is given by the equation:

$$E_2 = \frac{dX}{X} \div \frac{dV_2}{V_2} = \frac{X_2'}{\bar{X}_2}$$

X_2' - marginal productivity of V_2

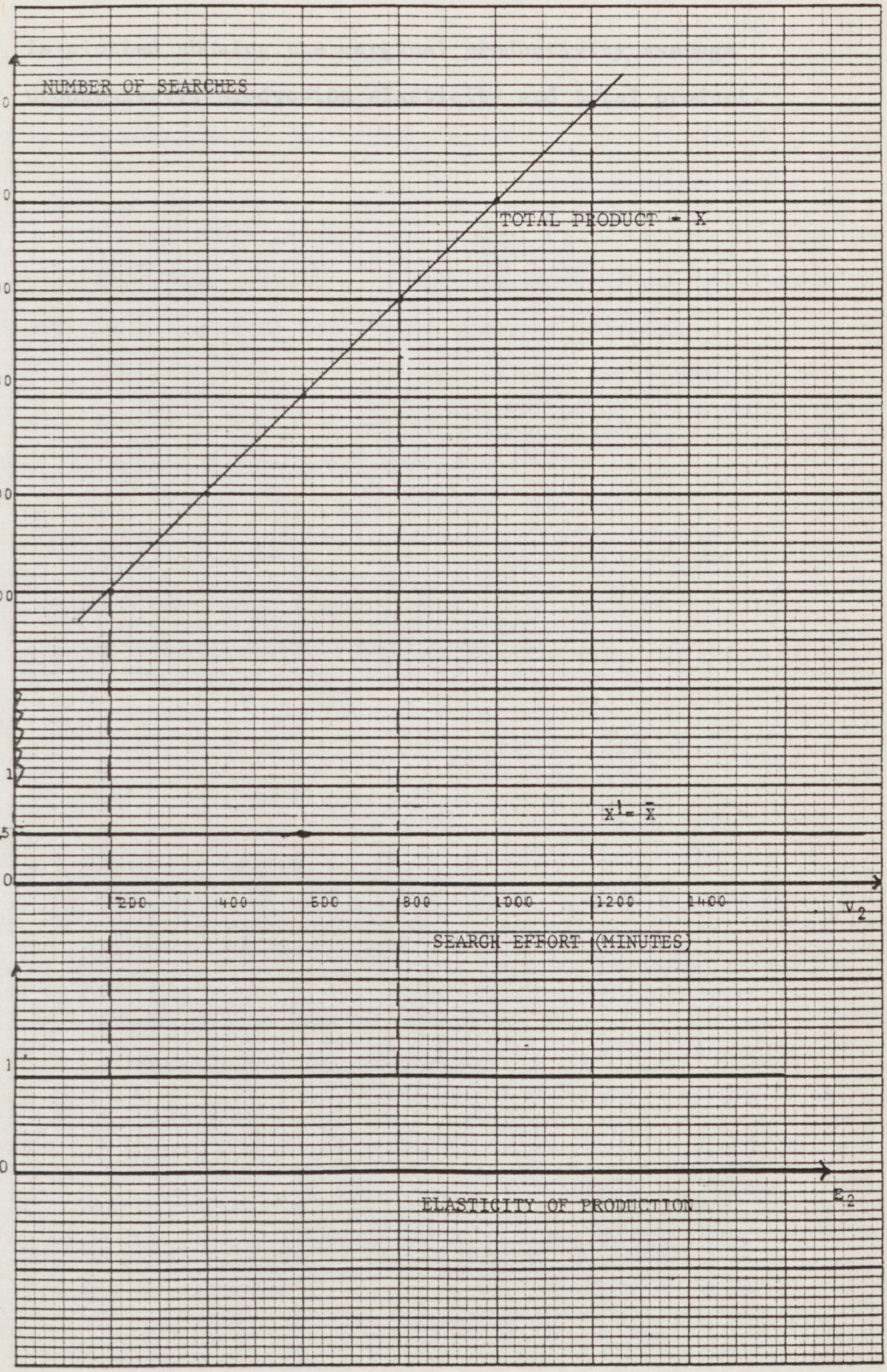
$\bar{X}_2$ - average productivity of V_2

The coefficient E gives the information of what happens when relative increments occur in the quantative value of the production factor and in the quantity of product. It is also the ratio between the marginal and average productivity, and in the present case equal to 1. This means that for system 1 increments in the quantity of factor V_2 (search effort) are producing constant returns of scale as opposite to decreasing returns of scale if factor V_1 (input effort) is taken as directly related to output quantity (number of searches produced). If and only if $E>1$ decreasing returns of scale will be obtained for factor V_2.

In this particular situation the technical decision should be to increase production as much as possible bearing in mind that factor V_1 (input effort) does not limit production, at least in quantitative terms. The optimal production point is then the maximum production point. It is valid to mention that the concepts of marginal productivity, average productivity and of elasticity of productivity are technical indicators rather than economic indicators.

The isoquants (Figure IV) for system 1 will have the form of points over horizontal lines which represent the volume of input in the system. In Figure V the increase in the variable factor

FIGURE V


NUMBER OF SEARCHES
600
500
400
300
200
100
TOTAL PRODUCT - X
1
0.5
0
x' = x̄
200
400
600
800
1000
1200
1400
V2
SEARCH EFFORT (MINUTES)
1
0
ELASTICITY OF PRODUCTION
E2

is plotted showing the marginal productivity, average productivity, production elasticity and total product.

The total product in this particular technical environment will grow indefinitely as quantities of the variable factor V_2 increases.

The previous analysis was made considering the technical relations of a production unit. It may not bring solutions for the information producer man and his decision problem but it will certainly help him to understand some technical relations which affect his production unit.

The next point will be to examine, for the same system S1 the cost function and how it could be related to the technical environment of the system.

In system S1 the total cost function will be given by the equation:

$$\Pi = C + P_1 V_1 + P_2 V_2 \qquad (9)$$

$$\Pi = 60 + 450 + 0.075\, V_2$$

C - fixed cost of annual materials, etc....

$P_1 V_1$ - fixed cost of input effort

$P_2 V_2$ - variable cost of search effort

The first two term of equation (9) being inescapable will not represent a decision variable once they have been incurred. Thus the cost of the variable factor of production is the one which will give most information for making decisions. The total VARIABLE cost for system S1 will become then:

$$\Pi = P_2 V_2 \qquad (10)$$

$$\Pi = 0.075\ V_2$$

P_2 - price of search effort

V_2 - quantity of search effort

From equation (4) we have:

$$V_2 = 2\ X$$

thus from (4) in (10) we have:

$$\Pi = 0.15\ X \qquad (11)$$

the marginal cost is:

$$\Pi' = \frac{d\Pi}{dX} = 0.15$$

and the average cost is:

$$\frac{\Pi}{X} = 0.15$$

As long as the conditions indicated in Appendix 6 remain constant the marginal cost of one search will be equal to the average cost and both will be constant (for the variable cost). In this new view the economies of scale shown in Table III will become constant returns of scale as in Table IV below:

Table IV

Number of Searches	Unit Cost:1 inclusive input costs	Unit Cost:2 only variable factor	Marginal Cost:3 Cost of one unit more
	£	£	£
50	10.3	0.15	0.15
100	5.2	0.15	0.15
200	2.7	0.15	0.15
500	1.2	0.15	0.15

In column 1, Table IV, the existence of economies of scale is due to the fixed cost of input been spread over increased units of output. Costs shown in column 2 and 3 in the same Table IV, based on VARIABLE COSTS, indicate the real cost of producing one unit more of output. All the costs indicated in Table IV would lead to the same decision of increasing the volume of output as much as possible, but unit cost in column 1 if considered alone could be misleading with respect to decisions in future investment and pricing policies.

The minimum cost condition for system S1 (variable costs only) is given by the marginal cost being equal to the average cost per search. A rational decision would be to increase output volume as much as an acceptable range of operational efficiency, assuming also constant price for V_2 and its marginal productivity constant over the 5 year period. The mathematical formulation for the minimum cost condition, using Lagrange's Method for a constrained minimum, would be:

$$\Pi = P_2 V_2 \quad \text{(cost function to be minimized)}$$

subject to the constraint that:

$$X = 0.5\, V_2 = X_0$$

$$X = X_0 \text{ (number of searches constant)}$$

We have then a new function $G(V_2)$ to be minimized

$$G(V_2) = P_2 V_2 - \lambda\left[X(V_2) - X_0\right]$$

$$G(V_2) = 0.075\, V_2 - \lambda\left[0.5\, V_2 - X_0\right]$$

the necessary condition for minimum cost is:

$$\frac{dG}{dV_2} = P_2 - \lambda \frac{X(V_2)}{dV_2} = 0,$$

thus

$$\frac{1}{\lambda} = \frac{X_2'}{P_2} \qquad (12)$$

and using the numbers of our example:

$$\lambda = \frac{0.075}{0.5} = 0.15 \qquad (13)$$

λ – Lagrange multiplier, a measure of the rate at which a small variation in the constraint will change the value of G so:

λ - marginal cost for factor V_2

P_2 - price of one unit of V_2

X_2' - marginal productivity of factor V_2

The necessary condition for a minimum cost, from equation (10), would be marginal cost being equal to the ratio between price and productivity of factor V_2. This is true for system 1 where it is equal to £0.15. So, as long as $P_2 = 0.075$ and $X_2' = 0.5$ the system will be working at minimum cost and the rational decision would be to increase output volume as long as operational efficiency permits.

If no consideration is given to output quality, any change from this situation would mean a bad economic decision for system 1. Suppose that the producer decides to alter the systems technique what will increase search productivity X_2' from 0.5 to 1.2 but assuming that with this new technique he will have to pay more for units of search effort V_2, now at £0.25 each unit. At minimum cost condition the new marginal cost will be £0.17 per search, a decision only acceptable if there is a need to increase operational efficiency. Figure VI shows for S1, average and marginal cost (variable factor), average cost including input effort costs and the total variable cost.

Another indicator of cost performance is the "Total cost elasticity". This shows the ratio between the relative variation in costs and the relative variation of output quantity, i.e., a measure of how increases in output quantity is affecting costs:

$$K = \frac{d\Pi}{\Pi} \div \frac{dX}{X} =$$

$$K = \frac{\Pi'}{\frac{\Pi}{X}} \qquad (14)$$

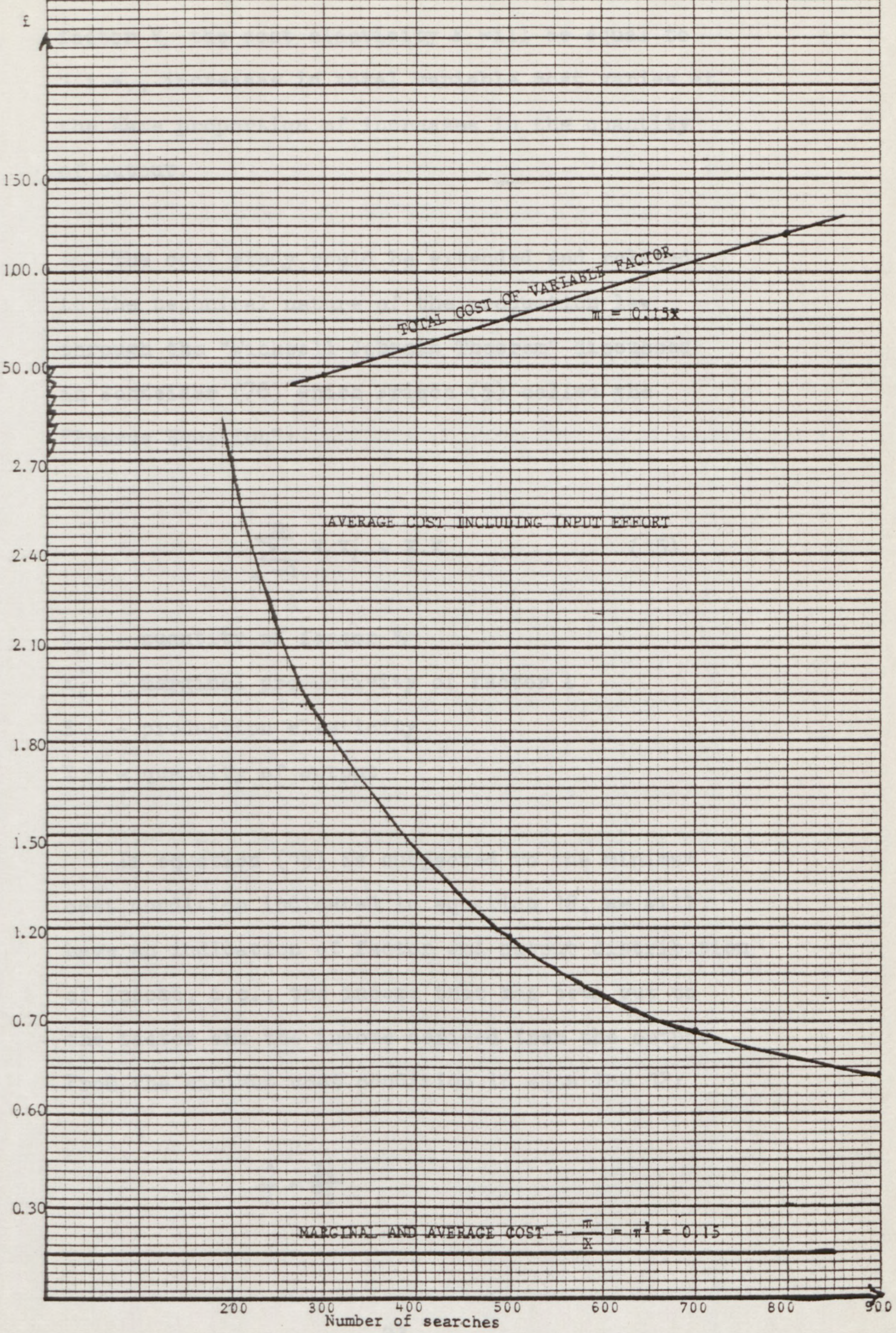
Π' - marginal cost

$\frac{\Pi}{X}$ - average cost

K = total cost Elasticity

In our example for S1 considering only the variable

FIGURE VI


£
150.0
100.0
50.00
2.70
2.40
2.10
1.80
1.50
1.20
0.70
0.60
0.30
TOTAL COST OF VARIABLE FACTOR
π = 0.15X
AVERAGE COST INCLUDING INPUT EFFORT
MARGINAL AND AVERAGE COST = π/X = π' = 0.15
200
300
400
500
600
700
800
900
Number of searches

factor V_2 the cost elasticity K will be equal to 1 i.e., increases in total variable cost varies at the same proportion of increases in the quantity of output.

The cost study could be extended and related to the technical nature of the production law through the "Wicksell-Johnson Theorem" discussed in Schneider (76) which Frisch (5) called the "Passus Equation":

$$\sum_{i=1}^{m} V_i X_i' = E.X \qquad (15)$$

V_i - quantity of factor V_i

X_i' - marginal productivity of factor i

E - production elasticity

X - quantity of output

If equation (15) is subjected to the minimum cost condition indicated in equation 12, we will have an indication of factor and output distribution of income, i.e., the income that has been put to the factor and the income derived from the output. From the minimum cost condition in equation 12:

$$\frac{1}{\lambda} = \frac{X_2'}{P_2}$$

then:

$$X_2' = \frac{P_2}{\lambda} \qquad (16)$$

applying equation (15) to our example, system S1, we have:

$$V_2 . X_2' = E.X \qquad (17)$$

Substituting from equations (4) and (16) in equation (17):

$$\underbrace{2X.P_2}_{I} = \underbrace{EX.\lambda}_{II} \qquad (18)$$

This relation brings together the technical and economic aspects of the production. In a rational situation I and II must be equal as they represent the distribution of income for factor quantity and output quantity.

The relation in equation (18) is also an indicator of how far the system is from the minimum cost condition. In the example, for system S1, we can verify equation (18) as the system is working in a condition of minimum cost, assuming that:

$X = 50$ (number of searches)

$P_2 = £\ 0.075$

$E = 1$

$\lambda = £\ 0.15$

and using equation (18):

$$2.(50).(0.075) = (1).(50).(0.15)$$

$$£\ 7.50 = £\ 7.50$$

If the system is spending more income with the production factor than the income generated by one unit of output, it would be an indication that the technique used by the system in the transforming process should be changed. Unless operational efficiency requires the contrary, at least the manager of the system will know how his system is operating.

There is another relation that brings together the technical and economic relations in a production unit (Frisch (5), Schneider (76)). The relation states that at minimum cost condition the average cost is equal to the product of the elasticity of productivity and the marginal cost; for the variable factor:

$$\frac{\Pi}{X} = E.\Pi' \qquad (19)$$

which for system S1 where:

$$\frac{\Pi}{X} = £0.15$$

$$E = 1$$

$$\Pi' = £0.15$$

is true for any amount of output.

If the relation indicated in equation (19) is used with the average cost shown in the first column of Table 1, where input costs are being considered, the elasticity of productivity for the variable factor (the only one which has a technical relation with the volume of output in our example) will have to assume values greater than one. An example for 500 searches is given below:

$$X = 500$$

$$\frac{\Pi}{X} = £1.20$$

$$E = 8.0$$

$$\Pi' = £0.15$$

A large value for E, the elasticity of productivity is shown for 500 searches if the average cost includes the fixed cost of input effort. This seems to indicate that if the average costs including the cost of input effort is assumed to be in minimum cost condition, the elasticity of productivity of the variable factor would have to be as high as 8.0, although it is known to be equal to 1 in our example for system S1. However the relation in equation (19) could give some indication on the use of the input effort, related to the number of searches and its cost. The nearer E is to 1 the better will be the use which has been made of the fixed input effort, in terms of the amortization of the input costs in relation to the incremental cost of the output.

This measure only relates the cost of the fixed factor to the incremental cost of the variable factor. It is not an optimal point which in this case would be to increase search effort (number of searches) as much as the operational efficiency would permit.

The average cost of input effort will be amortized to the incremental cost of the output when:

$$\Pi' = \frac{\Pi_I}{X} \quad \text{or } E = 1 \text{ for } \frac{\Pi_I}{X} = E.\Pi'$$

$\frac{\Pi i}{X}$ - average cost of input effort

Π' - marginal cost of one search

In system S1 this will happen at 3,000 searches, for time period of input effort. At 3,000 searches the average cost of the input effort is equal to the incremental cost of output.

This is only a <u>reference</u> point. At 3,000 searches the income generated by the variable factor (3,000 x £ 0.15) is equal to the income spent with the input effort (£ 450) (conditions set in Appendices 6 and 7)

We could then define "A" as the "rate of amortization of the input cost to the incremental cost of one search":

$$A = S - 1 \qquad (20)$$

where $$S = \frac{\frac{\Pi_i}{X}}{\Pi'}$$

In our example for system S1 A will assume values of:

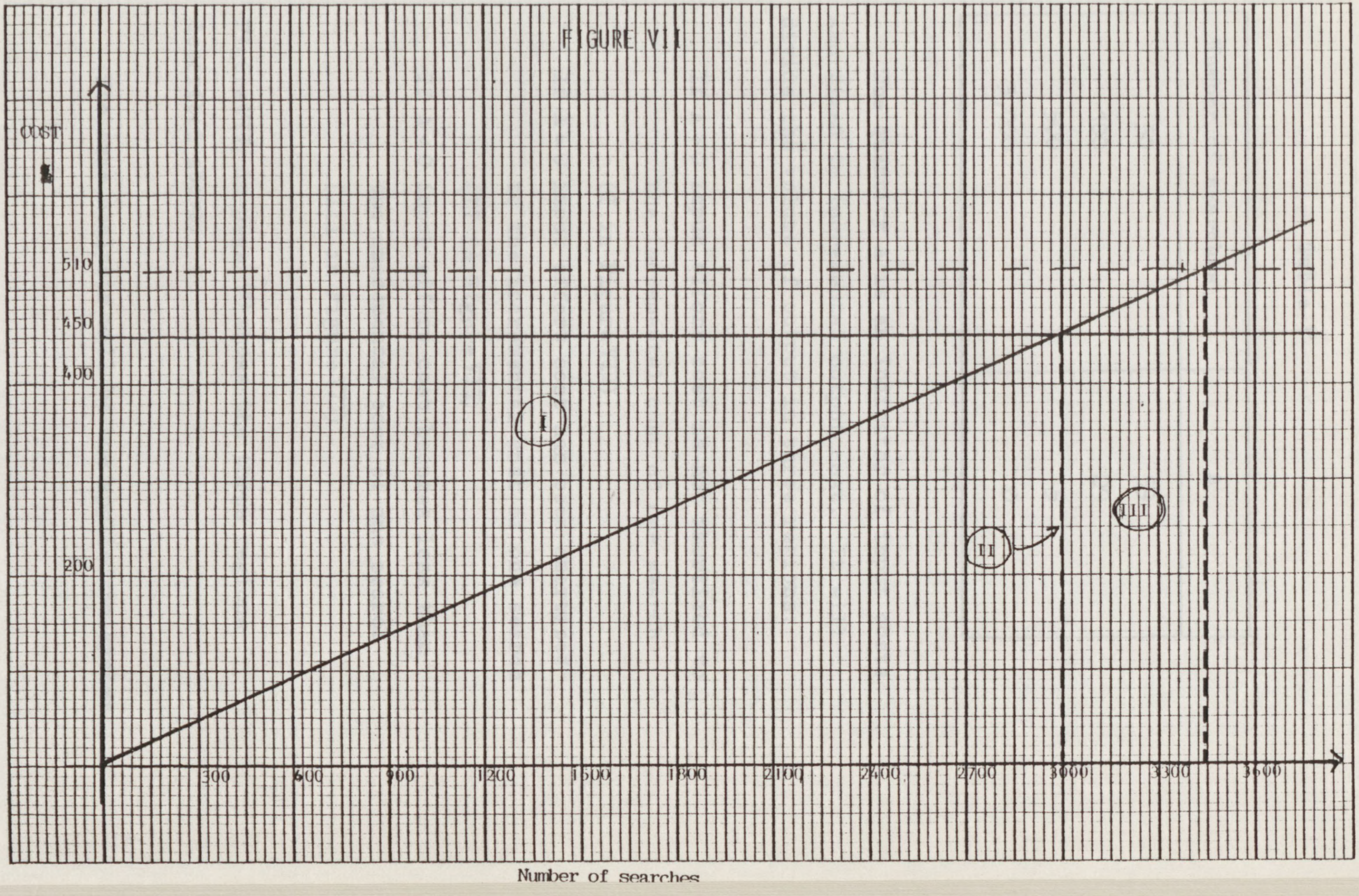

COST
$
510
450
400
200
I
II
III
300
600
900
1200
1500
1800
2100
2400
2700
3000
3300
3600
Number of searches

FIGURE VII

Table V

Number of searches	A
50	59
100	29
500	5
3,000	0

The quantity A is an indicator of input costs amortized to incremental output cost. It will divide the volume of output in three regions:

If $A > 0$ input effort cost is not amortized to the incremental cost of one search (I in Figure VII)

If $A = 0$ input effort cost has been amortized to the incremental cost of one search (II in Figure VII)

If $A < 0$ input effort cost becomes less than the incremental cost of one search (III in Figure VII)

Figure VII, in page 99 shows the three regions described above.

The same analysis will be now applied to system

S2 with an input rate of 10,000 documents per annum. As indicated in Appendix 6 the rate of input will influence search effort. Every batch of 10,000 cards will increase search time by two minutes.

The same assumptions regarding production factors for system S1 are applicable to system S2. The only variable factor of production is search effort. Again in this case both factors, V_1, input effort (input rate) and V_2, search effort, are for the same reasons discussed for system S1, not in a region of economic substitution. But in this case the <u>volume of input</u>, W, (different from the concept of the rate of input) will affect the productivity of factor V_2, search effort.

If we assume for system S2 the output (number of searches) as a function of search time, the production function will be:

$$X = \frac{1}{(0.0002).W} .V_2 \qquad (21)$$

X - output quantity

V_2 - search effort in minutes

W - volume of input in the system

The marginal productivity of factor V_2 will be:

$$X_2' = \frac{dX}{dV_2} = \frac{1}{(0.0002).W} \qquad (22)$$

The marginal productivity of V_2 shows an indirect relationship with the volume of documents in the system, W. The marginal productivity will assume values of:

1/2 for W = 10,000 documents

1/4 for W = 20,000 documents

1/6 for W = 30,000 documents

The table overleaf indicates the decreasing marginal productivity, X_2' as the volume of input, W increases:

Table VI

V_2: search effort (minutes)	NUMBER OF SEARCHES				
100	50	25	16	12	10
200	100	50	33	25	20
300	150	75	49	37	30
400	200	100	66	50	40
500	250	125	83	62	50
600	300	150	99	75	60
700	350	175	116	87	70
800	400	200	132	100	80
900	450	225	149	112	90
1,000	500	250	166	125	100
W: volume of input (Documents)	10,000	20,000	30,000	40,000	50,000

In any line of Table VI one can see that for the same amount of V_2 (search effort) less searches will be produced, as V_1 (input effort) increases W (volume of output). The isoquants showing the same output range, will also be points along horizontal lines which represent the input volume, as in Figure VIII, page 105 .

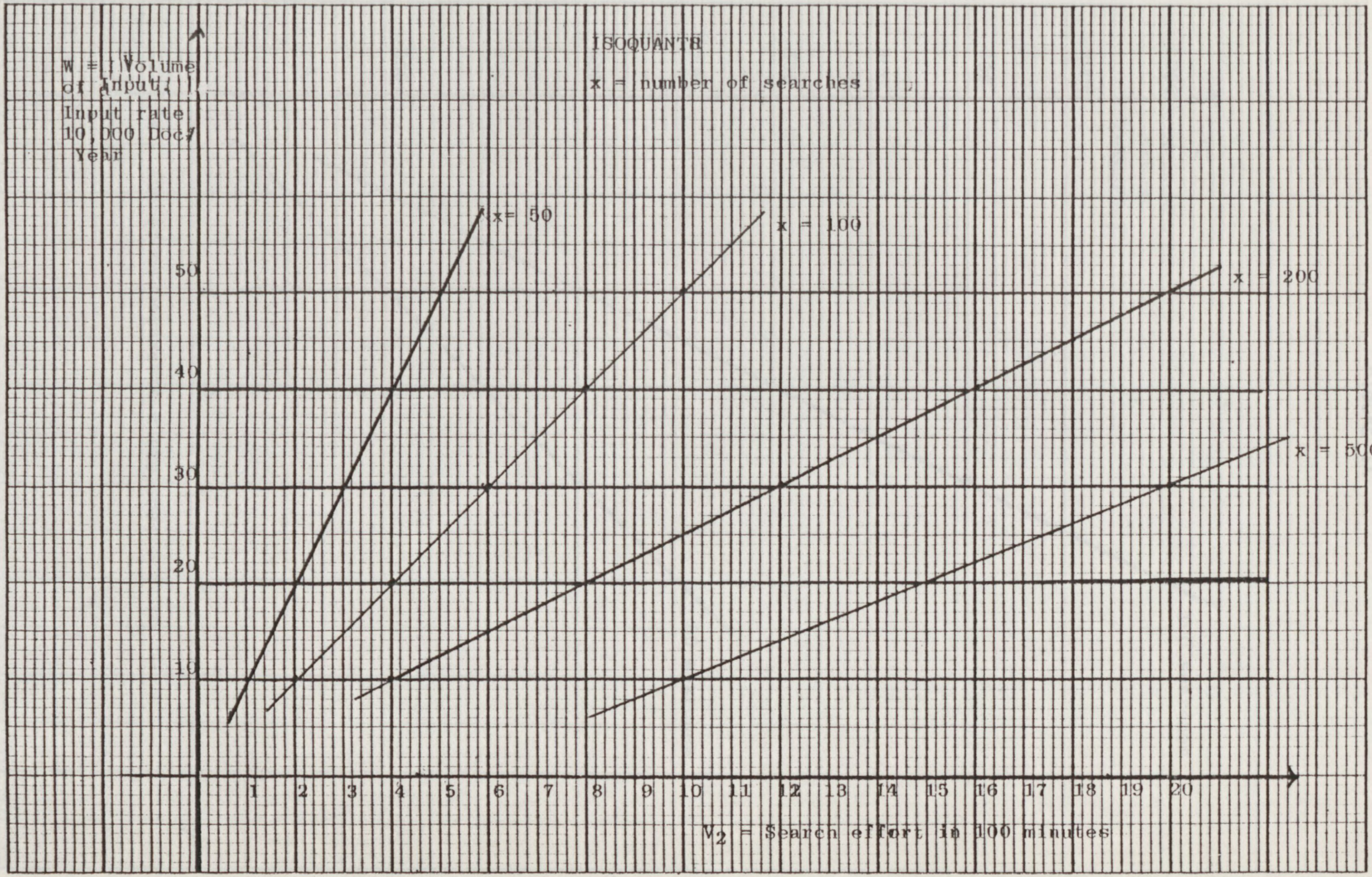
The imaginary lines connecting these points will have an inclination indicating that a greater quantity of factor of production V_2 is needed as the input rate increases.

The average productivity of search effort for system S2 will also be equal the marginal productivity but in this case for <u>each level of input volume, W</u>.

In system S1 we had constant returns of scale for all levels of input volume over the 5 years. In system S2 decreasing returns for factor V_2 (search effort) occur as the volume of input increases at a rate of 10,000 documents per year. In Figure IX this is plotted for 50 and 500 searches per year.

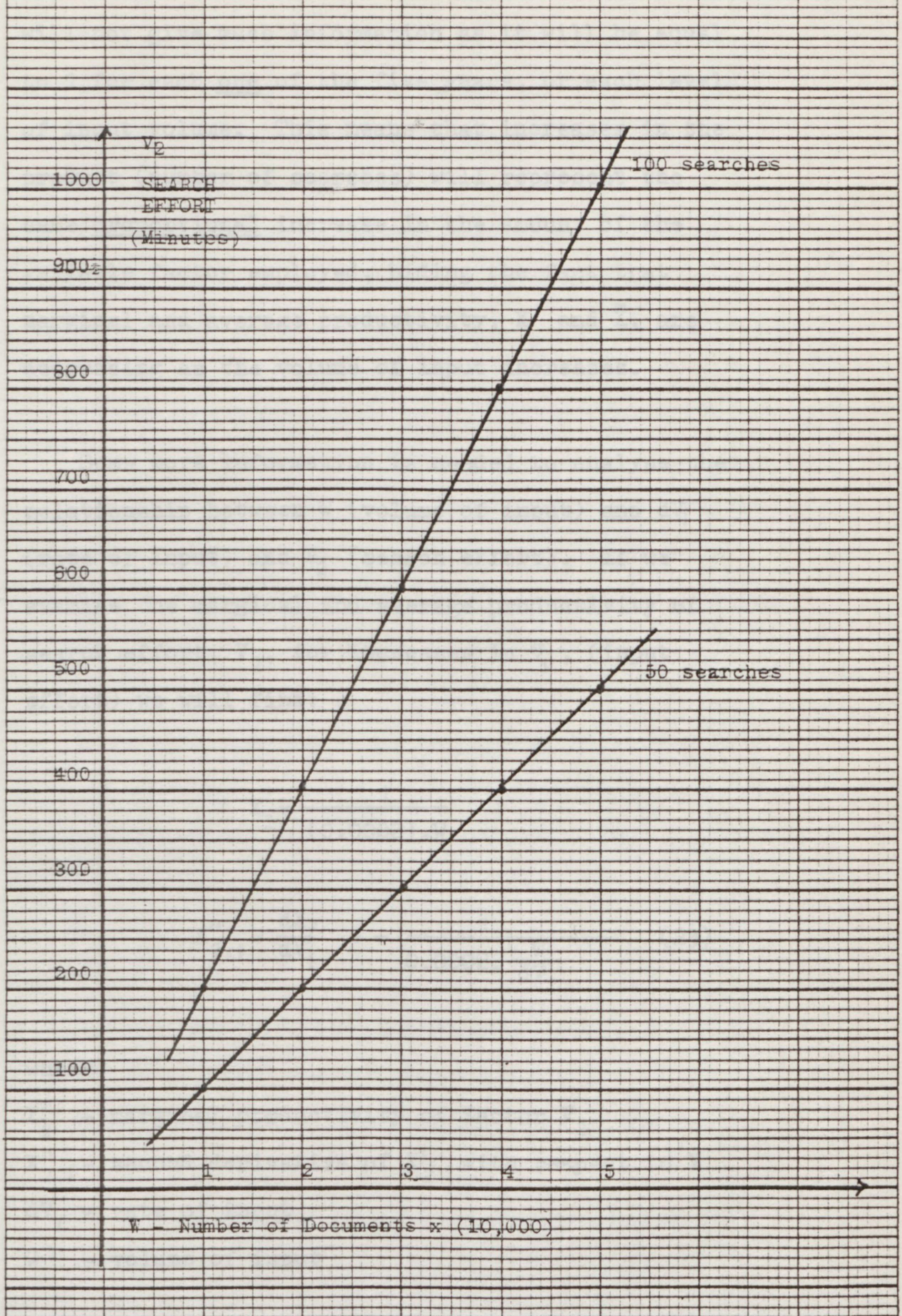
The elasticity of production (E) for factor V_2

FIGURE VIII



ISOQUANTS
x = number of searches
W = Volume of Input.
Input rate 10,000 Doc/ Year
x= 50
x = 100
x = 200
x = 500
50
40
30
20
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
V_2 = Search effort in 100 minutes

FIGURE IX


V2
SEARCH
EFFORT
(Minutes)
1000
900
800
700
600
500
400
300
200
100
100 searches
50 searches
1
2
3
4
5
W - Number of Documents x (10,000)

will not give much information as it will be equal to 1 for each one of the five years, or each level of input volume. This means that increases in the product (number of searches) will represent the same proportional increase in the amount of the variable factor employed, hiding the fact that marginal and average productivity, X' and $\bar{X}$, are decreasing as the volume of input increases.

Some more information is needed to analyse the relationship between W (volume of input) and dV_1 (rate of input) and V_2 (search effort). If we examine the marginal and average productivity of search effort, V_2, for increases in V_1, (input effort) we will find:

$$X_2' = \frac{1}{(0.0002).W}$$

$$X''_{2.1} = \frac{dX_2}{dV_1} = -\frac{1}{0.0002.\frac{W}{dV_1}} \qquad (23)$$

where:

X_2' - marginal productivity of factor V_2

$X''_{2.1}$ - second derivative of X_2' with respect to V_1

dV_1 - rate of input

W - volume of input

From equation (23) we can see clearly that there is a decreasing productivity for search effort related to increases in the volume of input.

There is no <u>technical</u> explanation for a system performing under this inverse relationship as:

$$\lim_{W \to \infty} X_2' = 0$$

Any system working under these technical conditions must change its technique of production to improve considerably or reverse the relation shown in equation (23).

The total cost function for system S2 would be:

$$\Pi = M + 0.225\ d\ V_1 + 0.075 .\ (0.0002 .\ (W)\ .\ X) \qquad (24)$$

where:

M - fixed cost of annual materials, etc.... (a)

0.225 dV - fixed cost of input rate (b)

0.075.(0.0002 (W) . X) - variable cost of search effort (c)

(all the conditions were as set out in Appendices 6 and 7)

As (a) and (b) are fixed after a decision has been made the costs directly influencing decisions are those associated with the variable factor V_2:

$$\pi = 0.075 \, . \, (0.0002 \, . \, W \quad . \, X) \qquad (25)$$

and the marginal cost will be:

$$\pi' = 0.075 \, . \, (0.0002 \, . \, W) = \frac{\pi}{X} \qquad (26)$$

and equal to the average cost (for the variable factor) for each level of input volume, W.

The cost elasticity, for the variable factor, is equal to 1, as marginal cost is equal to average cost. This means that costs are increasing at the same proportion of output <u>but for the same volume of input only</u>.

The marginal cost is increasing by £0.15 if the rate of input is equal to 10,000 documents per annum:

$$\pi' = 0.075 \, . \, (0.0002 \, . \, W)$$

if W = 10,000 documents:

$$\pi' = 0.15$$

The minimum cost condition for system S2 is given by the same method used in page 89 for system 1:

$$G(V) = 0.075\ V_2 - \lambda\left(\frac{1}{0.0002\ .W}\ .\ V_2\ - X_0\right)$$

a necessary condition for minimum cost being:

$$\frac{dG}{dV} = 0$$

which makes the minimum cost condition for system S1 to be:

$$\frac{1}{\lambda} = \frac{\frac{1}{(0.0002\ .\ W)}}{0.075} = \frac{X'_2}{P_2} \qquad (28)$$

X'_2 - marginal productivity of factor V_2

P_2 - price of one unit of V_2

In a minimum cost condition the marginal cost will be:

$$\Pi' = 0.075\ .\ (0.0002.W)$$

From equation (28) we may say that in the minimum cost condition the marginal cost is equal the ratio between the cost of the variable factor and its productivity.

System S2 is performing at minimum cost if it tends to increase output as much as possible in each scale of input volume.

If the volume of input W, increases at a rate of 10,000 documents a year the marginal cost will increase at £0.15 a year as indicated in equation (29):

$$\frac{\Pi'}{dW} = £0.15 \qquad (29)$$

Π' - marginal cost

dW - increase in volume of input (10,000 doc./year)

The volume of input increasing at this rate seems to indicate that there is no optimal economic adjustment for system S2 as marginal and average costs are increasing indefinitely to a limit of:

$$\lim_{W \to \infty} \Pi' = 0.075 \,.\, (0.0002\ W) = \infty \qquad (30)$$

In this case the rational economic decisions for system S2 would be:

1. to increase output (number of searches) as much as possible (and if it is possible) in every scale of input volume;
2. to change the production technique of the system to reverse, or at least to decrease the technical relation affecting search productivity;
3. to work with the system based on reasons of user needs but knowing that the system is uneconomical and will become worse over the years;
4. to close down system S2.

The technical relation affecting productivity of system S2 could be economically demonstrated using the minimum cost condition of equations (12) and (28) and the technical relation of equation (15). From equations (12) and (28) we have:

$$\frac{1}{\lambda} = \frac{X_2'}{P_2} \quad \text{(minimum cost condition)}$$

that can be written:

$$X_i' = \frac{P_i}{\lambda} \qquad (31)$$

From equation (15) we have:

$$\Sigma V_i X_i' = E X$$

that for system S2 would be:

$$V_2 \cdot X_2' = E \cdot X \qquad (32)$$

For system S2 the production function was said to be:

$$X = \frac{1}{0.0002\ W} \cdot V_2$$

and the quantity of V_2 needed for X units of output:

$$V_2 = (0.0002.W) \cdot X \qquad (33)$$

Applying (31) and (33) in (32) and knowing that E = 1 at the minimum cost condition, we have:

$$\left[(0.0002.W) \cdot X\right] P_2 = E.X.\lambda \qquad (34)$$

The technical/economic relation pointed out in equation (34) indicates the income that was spent for factor V_2 , search effort, on the left hand side. On the right hand side is the income generated by the amount of output (number of searches).

If the volume of input increases by a rate of 10,000 documents a year we may say that the income generated by the output has to increase at a rate of £0.15 per unit of output to balance the factor income. The value of £0.15 is the rate of increase in marginal cost due to increases in the volume of input. Table VII gives a numerical example of a relation shown in equation (34) for 50 searches and a constant price of £0.075 per unit for factor V_2.

Table VII

(50 searches)

VOLUME OF INPUT W	FACTOR INCOME $[(0.0002W).X]P_2$	OUTPUT INCOME $\lambda.X$	MARGINAL COST λ	RATE OF INCREASE IN MARGINAL COST λ'
10,000	£ 7.50	£ 7.50	£0.15	0.15
20,000	£15.00	£15.00	£0.30	0.15
30,000	£22.50	£22.50	£0.45	0.15

Table VII seems to indicate that for the same amount of output the income spent in the variable factor is increasing by a rate of λX or 0.15 X, when the productivity of that factor is decreasing. This could be called Rate of Income Increase for the Variable Factor, for the same amount of output due to a decreasing productivity of that factor, and defined by:

$$L = \lambda' . X$$

L - rate of income increase for the variable factor

λ' - rate of increase in marginal cost

X - output quantity

The rate of amortization of the input cost to the marginal cost of a search assumes for system S2 a different aspect as the marginal cost of one search is increasing over the years as a function of input volume.

In system S1 we calculated the rate of amortization of input costs applying equation (20):

$$A = S - 1$$

where:

$$S = \frac{\frac{\Pi_i}{X}}{\Pi'}$$

$\frac{\Pi_i}{X}$ - average cost of input effort

Π' - marginal cost of one search

If we apply this to system S2 the number of searches which will amortize input costs will decrease over the years as marginal cost increases. This shows the increasing income that has to be spent with the variable factor.

It could be suggested, however, that a point of amortization for the input cost could be the number of searches that equals the cost of input to the rate of increase of marginal cost of the variable factor. With 15,000 searches a year, the fixed cost of input (£2,250) would be equal to the yearly increasing marginal cost of the variable factor (£0.15), when:

$$A' = S' - 1$$

where:

A' - rate of amortization of the input cost to the rate of increase in marginal cost of the variable factor

and S' is:

$$S' = \frac{\frac{\Pi_i}{X}}{\lambda'}$$

where:

$\frac{\Pi_i}{X}$ - average cost of input effort

λ' - rate of increase in the marginal cost of the variable factor

It has to be pointed out that this is only a reference point. At 15,000 searches a year the average cost of input effort would be equal to the increase in marginal cost of the variable factor caused by operational conditions of decreasing productivity of that factor. At this point the income that the system is generating through its output is equal to the income spent in the fixed input factor (15,000 x £0.15 = £2,250), otherwise it would hide the decrease in productivity that 3,000 searches would show (3,000 x £0.75 = £2,250).

In Table VIII below data are presented which summarise the search cost at various input volumes. These data are derived from hypothetical costings presented by Bottle in 1976 (75) but which were nevertheless based on actual equipment costs, wage rates, overheads, timings, etc.

Table VIII

Input Volume W	Marginal Cost of V_2	Number of Searches A = 0	Rate of increase in marginal cost λ'	Number of seaches $A' = 0$
10,000	0.15	15,000	0.15	15,000
20,000	0.30	7,500	0.15	15,000
30,000	0.45	5,000	0.15	15,000
40,000	0.60	3,750	0.15	15,000
50,000	0.75	3,000	0.15	15,000

It must be pointed out now that the whole analysis which has been presented was made taking into account the conditions set in pages 60 to 66.

One of those conditions was <u>constant prices</u> during the period of analysis. The analysis could not be undertaken for an environment of changing prices. This indicates that <u>inflation</u> was not considered during the period of analysis.

A few words have to be mentioned of how it would affect our model of analysis.

The model used comprises two kinds of relationship:

a) technical relations,

and

b) economic relations.

The technical relations, as discussed in the model, would not suffer from any affect of changing prices. They hold independently of inflation* and

* In the real world it may happen that an alternative process becomes preferred to an existing process because its cost has increased relatively less, so that it becomes economically viable through costing less than the process initially used (e.g. computer systems today relative to manual systems in say 1950).

they are related to the transformation process used by the production unit.

The economic and the technical/economic relations will obviously be influenced by the changing prices of inflation. In this case the analysis has to be adjusted to the new market prices and this could be easily done. The important parts of the model are the new kind of relationships that are presented and the comparisons that make possible some sort of economic evaluation of the transformation process in information systems. Nevertheless, the adjustment to a new order of prices is clear and quickly possible if the system is working with the same technical relations, i.e., the transformation process of production remains unchanged.

If prices have increased by, for example, 60% from one period of analysis to another, the unit price of production factor V_2 = £0.075 will increase to £0.12. The cost function for system S1, equation (11) would become:

$$\Pi = 0.24 \,.\, X \quad \text{(cost function)}$$

$$\Pi' = 0.24 \quad \text{(marginal cost)}$$

$$\frac{\Pi}{X} = 0.24 \quad \text{(average cost)}$$

for:

$$V_2 = 2 \cdot X \quad \text{(technical relation)}$$

The minimum cost condition, equation (12) would be:

$$\frac{1}{\lambda} = \frac{X_2}{P_2} =$$

$$\lambda = \frac{P_2}{X_2} = \frac{0.12}{0.5} = £0.24 \text{ (marginal cost at the minimum cost condition)}$$

All the other adjustments would follow from that. The quantity 0.5 for X_2' (marginal productivity of factor V_2) remains unchanged as X_2' represents a technical relation, totally independent of prices.

It is not possible to bring into the model of analysis a dynamic adjustment to changing prices and this is typical of the greater part of the economic analysis.

CHAPTER IV

CONCLUSIONS

1. Conclusions

The economic analysis, based in the theory of production, was applied to the environment of documentary information systems and gave the rise to the following conclusions:

I. Economic analysis will be a good tool for decision making, planning and understanding the concept of efficiency in information systems;

II. A production process in the technical sense of the word need not necessarily create value or use. If a product (or information) becomes valueless owing to a state of the market (or user judgement) the process that produces it is still a production in the technical sense of the word;

III. Every information system has a production factors diagram that must be studied and understood if economic analysis is to be performed. The quantity of product and its cost vary if factors determining capacity remain constant while other factors may vary. The last are called variable factors of production and the first are called fixed factors of production.

IV. Input effort was considered in the model of analysis a fixed factor as it varies in fixed or quasi-fixed quantities due to operational requirements; it has some characteristics of indivisibility but it does not limit production though it affects the adjustment of other factors of production;

V. Input effort and search effort are not in a substitution relationship. It is not possible to increase the number of searches demanded from the system by increasing the amount of input effort and decreasing the amount of search effort in that particular information system;

VI. Every information system has technical relationships and economic relationships. The technical relationships link the production factors and the output quantity. In the economic relationships consideration is given to the cost of these production factors. These relationships will be different for different information systems providing different services;

VII. In the cost study it was found that orthodox accounting methods, once they have reduced costs to a monetary unit, are homogeneous in behaviour and equal in importance. Average costs (or unit costs derived from average costs) for information services assume that the volume of output is the only variable influencing costs. Cost behaviour is affected by several variables that probably act as if they are interrelated. Average costs can not be generalised for cost forecasting, planning and decision making. Information systems are normally operating with different operational conditions and different technical relations influencing the quantity of output which is produced by the system;

VIII. Marginal cost could be a better indicator for decision making in information systems. Average costs may be influenced by fixed, indivisible, inescapable after they have been incurred production factors which would not be clearly indicated in an accounting cost analysis;

IX. The concept of production capacity was suggested for information systems. Production capacity will differ for different information services. The input rate, i.e., the rate of input that is placed into the system periodically will add to form the input volume. The input volume (number of references or documents held in the system) does <u>not</u> determine capacity, i.e., it does not restrain output volume, number of searches. The input rate, however, and thus the input volume increases the capacity of the system if the volume of input is accepted as a fixed factor; this could modify the concept of economies of scale in information systems;

X. The technical relationships and the economic relationships have suggested the introduction of new measures of economic adjustment for the evaluation of information systems;

XI. The model and the effect of inflation: the model used for the analysis comprises two kinds of relations, technical relations and economic relations. The technical relations are associated with the transformation process used by the production unit. These technical relationships will not be effected by changing prices, i.e., inflation.

The economic relationships will have to be adjusted in a situation of changing prices. However, this could be easily done as it has been demonstrated at the end of Chapter III of this work.

2. Suggestions for further research in the field

This research work presents new views of economic and cost analysis for documentary information systems.

The author believes that this analysis could be applied to different systems operating different services. Such studies would be a profitable line of research to validate a theory of the economics of information systems.

Another line of investigation could be the concept of production capacity in actual existing systems. What would be the optimal scale of output volume for a system with a specific transforming process? At which stage of output volume should the transformation process be changed to reach a better economic adjustment?

It is also, worthwhile to investigate the different production factors for systems providing different kinds of service and the real existence of economies of scale as a function of increasing output volume.

The author does not believe that these new concepts will be accepted promptly by the whole information science community. However, he is sure that this could be the first step for a formulation of a body of knowledge on the economics of information systems.

APPENDIX 1

APPENDIX 1

Input into the system (1) initial operations (2) input itself (Table 10)

Service	Volume	PERSONNEL				MACHINE			MATERIALS		
		Qualification	Total time in hours per annum	Unit time in minutes	Unit cost in Belgian francs	Total time in minutes per annum	Utilization costs in Belgian francs per annum	Unit cost in Belgian francs per annum	Total cost in Belgian francs per annum	Unit cost Belgian francs	Total unit cost in Belgian francs
1)	27 000	Operators	5 000	3.4	21.6	–	300 000	11	–	–	77.0
2)	27 000	–	–	–	–	12 000	1 200 000	44.6	–	–	
1) 2)	3 000	A1	144	2.88	17.3	–	–	–	6 000	2	19.3
1)	2 000	Administration clerk	165	4.95	22.3	–	–	–	–	–	40.38
2)	2 000	" "	120	3.6	16.2	–	–	–	3 750	1.88	
1)	26 000	Key punchers	870	2.01	8.04	52 000	7 300	2.81	20 000	0.77	13.34
2)	26 000	A2	33	0.08	0.36	2 000	33 400	1.28	2 000	0.07	
1) 2)	30 000										22
1)	3 000		–	–	–	1 000	5 000	1.67	–	–	95
2)	3 000	–	–	–	–	600	100 000	33.33	–	–	
1) 2)	2 500	A2	950	22.8	102	–	–	–	–	–	102

APPENDIX 1

Input into the system (1) initial operations (2) input itself (Table 10)

Service	Volume	PERSONNEL				MACHINE			MATERIALS		
		Qualification	Total time in hours per annum	Unit time in minutes	Unit cost in Belgian francs	Total time in minutes per annum	Utilization costs in Belgian francs per annum	Unit cost in Belgian francs per annum	Total cost in Belgian francs per annum	Unit cost Belgian francs	Total unit cost in Belgian francs
1)	27 000	Operators	5 000	5.4	21.6	–	300 000	11	–	–	77.0
2)	27 000	–	–	–	–	12 000	1 200 000	44.4	–	–	
1)	3 000	A1	144	2.88	17.3	–	–	–	6 000	2	19.3
2)											
1)	2 000	Administration clerk	165	4.95	22.3	–	–	–	–	–	40.38
2)	2 000	" "	120	3.6	16.2	–	–	–	3 750	1.88	
1)	26 000	Key punchers	870	2.01	8.04	52 000	7 300	2.81	20 000	0.77	13.34
2)	26 000	A2	33	0.08	0.36	2 000	33 400	1.28	2 000	0.07	
1) 2)	30 000										22
1)	3 000	–	–	–	–	1 000	5 000	1.67	–	–	95
2)	3 000	–	–	–	–	600	100 000	33.33	–	–	
1) 2)	2 500	A2	950	22.8	102	–	–	–	–	–	102

APPENDIX 1

Retrospective search

SERVICE	Number of questions per annum	PERSONNEL				MACHINE			MATERIALS		Total unit cost in Belgian francs
		Qualification	Total time in hours per annum	Unit time in minutes	Unit cost in Belgian francs	Total time in minutes per annum	Total cost in Belgian francs	Unit cost in Belgian francs	Total cost in Belgian francs per annum	Unit cost in Belgian francs	
SD1	1 160	University	800	41	328	9 000	900 000	776	–	–	1 104
SD3	375	A1	1 500	240	1 440	–	–	–	–	–	1 440
SD4	600	1) A1	80	8	48	–	–	–	–	–	
		2) A2	40	4	18	–	–	–	–	–	
		3) A2	100	10	45	–	–	–	–	–	111
SD6	100	1) A1	100	60	480	–	–	–	–	–	
		2) A2	50	30	135	3 000	50 000	500	5 000	50	1 645
		3) A1	100	60	480	–	–	–	–	–	
SD7	200	1) A2	1 500	450	2 025	–	–	–	–	–	
		2) A2	100	30	135	–?	400 000	2 000	–	–	4 160
SD8	10 000	A2	2 000	12	54	–	–	–	–	–	54
SD9	50	University	12	14.4	115.2	50	10 000	200	–	–	315.2
SD11	60	University	1 000	1 000	8 000	–	–	–	–	–	8 000
SD12	60	University 1)	60	60	480	?	100 000	1 666.7	–	–	2 506.7
		A1 2)	60	60	360						

APPENDIX 2

APPENDIX 2

System	Location	Variable cost per search:$	Size of file searched: items	File storage medium	Comments
S.19	EU.	133.70	up to 1,000,000	Data cell	1971 data
S.19	EU.	57.61	up to 1,000,000	Data cell	Predicted for end 1972
S.9A	EU.	36.75	up to 100,000	Mag. Tape	Estimated by operator
S.1	U.S.	33.60	160,000	Disc	
S.11	EU.	22.30	516,700	Mag. Tape	
S.14	EU.	10.46	23,000	Disc	
S.13	EU.	9.17	40,000	Disc	
S.12	EU.	4.56	22,000	Disc	
S.18	EU.	3.30	40,000	Disc	Based on published data

Table 14: Variable costs of retrospective searches.

APPENDIX VI

IR COSTS

RETROSPECTIVE SEARCH COSTS

All costs shown in U.S. dollars

	3.1	3.9A	3.11	3.12	3.13	3.14	3.18	3.19
On-line (interactive) or batch processing	batch	batch	batch	batch	batch	batch	on-line	on-line
Data base								
(a) Cost per year	377,860	5,306 (CAC)	33,810[7]	22,364	123,103	52,979	70,000	110,548
(b) Cumulative cost	2,325,292	-	-	36,717	223,824	122,259	-	-
(c) File storage cost	1,296	-	9,800	-	-	98	800	108,700
File characteristics								
(d) Nat. lang./controlled vocabulary	CV	CV + NL	CV	CV	CV	CV	CV	CV + NL
(e) No. of indexing terms per item	35-40	-	-	11.6	10	8	-	-
(f) Size of file searched (items)	160,000	50 - 100 K	516,700	22,000	40,000	23,000	40,000	up to 1,000,000
User Characteristics								
(g) No. of searches per year	1,000	200	1,600	150	3,600	1,200	2,625[5]	1,800[8]
(h) No. of terms per search	n.a.	-	115[4]	15	30	5	-	-
(j) Search formulation costs per year	13,500	-	3,234	183	3,594	3,675	2,625	-
Output Characteristics								
(k) Computer processing cost per year	13,600	7,322	31,850	529	27,630	6,431	3,938	43,045[6]
(l) No. of search runs per year	118	-	57	100	400	240	-	-
(m) Ave. computer time per run	-	-	387 mins		-	18.75 min	-	-
(n) No. of hits per search (ave.)	-	-	248	-	15	25	-	-
(o) Output printing costs per year	-	-	-	-	-	-	-	-
(p) Output checking costs per year	6,500	-	-	-	1,801	2,450	-	-
(q) Reproduction costs per year	-	-	-	-	-	-	-	-
(r) Mailing & distribution costs per year	-	-	588	-	-	-	-	-
(s) Communications, terminals cost per year	-	-	-	-	-	-	2,100	80,221[6]
(t) Form of output	citations	citations	citations	abstracts	abstracts	as required	abstracts	variable
(u) Index production costs per year	9,400[1]	-	-	794	-	-	-	-
D/B cost per search (for one year's file) = $\frac{a+c}{g}$	379.156	-	27.256	149.093	34.20	44.231	26.971	-
Variable cost per search = $\frac{j+k+o+p+q+r+s}{g}$	33.60	36.75[2]	22.295	4.562	9.174	10.463	3.30	133.701[7] 57.62[8]
Comp. processing cost per record searched = $\frac{k+o}{f}$	0.085	-	0.062	0.024	0.691	0.280	0.098	-
Comp. processing cost per search term = $\frac{k+o}{h \times g}$	-	-	0.173	0.236	0.256	1.072	-	-
Total cost per hit = $\frac{a+c+j+k+o+p+s}{g \times n}$	-	-	0.198	-	2.891	2.188	-	-

Notes

1. Includes $5000 for dual dictionary.
2. Estimate only.
3. Includes cost of density conversion.
4. Includes automatic posting on generic terms.
5. Costs are based on use rate of 15 searches per day.
6. For 1971.
7. Data for 1971.
8. Estimate for end of 1972.

APPENDIX 3

SDI COSTS

All costs shown in U.S. dollars

SYSTEM: DATA BASE:	S.4 INSPEC	S.7 CT/CRAC/CAC	S.8 ISI	S.9A CAC	S.9B RA.I REV.	S.10 EXC. MED.	S.11 MEDLARS	S.12 S.12	S.13 S.13	S.20 CT	S.21 COMPENDEX
File Costs:											
(a) Tape subscription	2,205	7,644[1]	4,960[5]	5,306	3,800	15,685	33,075[6]	-	-	1,850	6,800
(b) Freight charges	-	-	-	(incl. above)	-	(incl. above)	(incl. above)	-	-	150	
(c) Handling/ordering	-	-	-	-	-	-	-	-	-	-	-
(d) File conversion	-	incl. under (q)	294	-	-	796	-	-	-	-	2,328
(e) Tape storage	-	-	tapes not kept	-	-		charge to IR	-	-	-	-
(f) Other	490	-	-	-	-	-	-	-	-	-	-
(g) TOTAL (a -f)	2,695	7,644	5,254	5,306	3,800	16,481	33,075	22,364	123,103	2,000	9,128
File Characteristics											
(j) Records per year	148,000	340,000[2]	350,000	340,000	140,000	50,000	220,000	13,400	22,000	130,000	72,000[9]
(k) Number of tapes per year	50	26	52	52	36	52	12	50	24	26	12
(l) File size per search	(A 1,680 (B 480 (C 800	See note (3)	6,730	6,538	3,889	3,000	6,111	268	917	5,000	6,000
User Characteristics:											
(M) No. of users	200	270	185	400	400	30	150	400	400	60	200
(m) No. of profiles/searches	-	270	504	950	950	30	150	400	400	200	200
(n) Profile maintenance costs (staff & computer time)	14,700	1,419	8,012	613	613	735	(5,000)[7]	(500)[7]	732	(500)[7]	3,267
(o) Ave. terms per profile	-	75	32	10	10	17	-	24	60	6	22
(p) Ave. hits per profile per year	-	1,156	665.5	263.2	210.5	915.2	961	625	350	156	360
Output Characteristics											
(q) Computer processing costs per year	19,600	26,754	19,339	6,515	4,510	11,148	7,497	1,323	28,492	2,205	28,198
(r) Av. comp. time per run	-	10 hrs	2.53 hrs	5.11 hrs	5.11 hrs	3.5 hrs	5.1 hrs	11 min CPU 83 min wait	-	45-50 min	-
(s) No. of runs per year	50	[illegible]	52	52	36	52	12 (36)	50	24	26	12
(t) Output printing costs per year	1,225[4]	2,205[4]	1,454	-	-	-	-	-	3,234[8]	-	-
(u) Reproduction costs per year	-	-	-	-	-	-	-	-	-	-	-
(v) Mailing & distrib. costs	1,666	5,439	892	-	-	-	735	-	-	-	-
(w) Royalties per year	-	incl. under (a)		-	-	-	-	-	-	-	1,409
D/B cost per reference = $\frac{g}{j}$	0.0182	0.023	0.0150	0.0156	0.0271	0.330	0.150	1.669	5.596	0.0154	0.127
D/B cost per user = $\frac{g}{M}$	13.48	28.31	28.4	13.26	9.50	549.4	220.5	55.91	307.76	33.33	45.64
Variable cost per user = $\frac{n+q+t+u+v+w}{M}$	186	169.7	161	17.7	12.8	396.1	88.2	4.6	81.1	45.1	164.4
Processing cost per record = $\frac{q+t}{j}$	0.141	0.079	0.059	0.019	0.032	0.223	0.034	0.099	1.295	0.017	0.392
Processing cost per search term = $\frac{q+t}{m \times o}$	-	1.321	1.291	0.686	0.475	21.86	-	0.138	1.187	1.838	6.409
Processing cost per item output = $\frac{q+t}{m \times p}$	-	0.086	0.062	0.026	0.023	0.406	0.052	0.005	0.204	0.071	0.392
Total cost per item output = $\frac{g+q+t+w+n}{m \times p}$ (excl. repro. & distribution)	-	0.154	0.102	0.050	0.045	1.033	0.316	0.097	1.111	0.151	0.583

Notes

1. Represents only part of total cost of data base used; remainder charged to other services.
2. Total files searched are CT 130,000 items: CAC 340,000: CBAC 30 000.
3. Dependent on data base used.
4. Output stationery cost only.
5. S.8 pays only 62% of $8000 subscription (based on usage); remainder paid by another information unit.
6. In this case data base is acquired in exchange for share of input: cost shown is of input preparation.
7. Notional figure used in calculating unit costs below.
8. Output checking costs.
9. Since this figure was published, the size of this data base has risen to 102,000 items per year.

APPENDIX 4

APPENDIX 4

SYSTEM NUMBER IN THE ORIGINAL TABLE (S)	VARIABLE COST OF SEARCHING PER YEAR (COST OF PROFILE MAINTENANCE, COMPUTER PROCESSING AND DISTRIBUTION) (I)	NUMBER OF PROFILES PER SEARCH (II)	AVERAGE NUMBER OF TERMS PER PROFILE (III)	NUMBER OF RECORDS PER YEAR (IV)	AVERAGE NUMBER OF HITS PER PROFILE (V)	VOLUME OF OUTPUT, NUMBER OF ITEMS (REFERENCES) PER YEAR (ITEM II MULTIPLIED BY ITEM V) (VI)	NUMBER OF RUNS PER YEAR (VII)	VARIABLE COST PER PROFILE PER RUN (ITEM I DIVIDED BY ITEM II AND MULTIPLIED BY ITEM VII) (VIII)	COST PER ITEM OF OUTPUT (VARIABLE) (ITEM I DIVIDED BY ITEM VI) (IX)	COST OF COMPUTER PROCESSING PER RUN (ITEM k IN THE ORIGINAL TABLE DIVIDED BY ITEM VII) (X)	COST OF PROFILE MAINTENANCE PER RUN (ITEM j IN THE ORIGINAL TABLE DIVIDED BY ITEM VII) (XI)	NUMBER OF PROFILES PER RUN PER YEAR (ITEM II MULTIPLIED BY ITEM VII) (XII)	VOLUME OF OUTPUT (REFERENCES) PER RUN (ITEM VI DIVIDED BY ITEM VII) (XIII)
4	35,966	200	-	148,000	-	-	50	3.60	-	392.00	294.00	10,000	-
7	43,612	270	75	340,000	1,156	312,120	26	6.20	0.1397	1,029,00	439.19	7,200	12.005
8	28,243	504	32	350,000	665.5	330,372	52	1.08	0.0855	371.90	154.07	26,208	6,353
9A	7,128	950	10	340,000	263.2	250,040	52	0.14	0.0285	125.28	11.79	49,400	4,808
9B	5,123	950	10	140,000	210.5	199,975	36	0.15	0.0256	125.27	17.03	34,200	5,554
10	11,883	30	17	50,000	915.2	27,456	52	7.60	0.4328	214.38	14.13	1,560	528
11	13,232	150	-	220,000	961	144,150	36	2.40	0.0918	208.25	138.89	5,400	4,004
12	1,823	400	24	13,400	625	250,000	50	0.10	0.0073	26.46	10.00	20,000	5,000
13	29,224	400	60	22,000	350	140,000	24	3.10	0.2070	1,187.17	30.50	9,600	5,883
20	2,705	200	6	130,000	156	31,200	26	0.50	0.0867	84.81	19.23	7,200	1,200
21	31,465	200	22	72,000	360	72,000	12	13.10	0.4370	2,349.83	272.25	2,400	6,000

APPENDIX 5

APPENDIX 5

Number and type correlation	Dependent variable Y_i	Independent variable X_i		Number of cases	correlation index	determination index
SC 1	variable cost per year	number of searches per year	X1	11	-0.023	0.0005
SC 2	" " " "	number of runs per year	X2	11	-0.45	0.20
SC 3	" " " "	number of records per year	X3	11	-0.077	0.0006
SC 4	cost per profile per run	searches terms per profile	X4	9	0.23	0.05
SC 5	" " " " "	volume of output per run	X5	10	-0.17	0.03
SC 6	" " " " "	number of records per run	X6	10	0.16	0.02
SC 7	" " " " "	file size per search	X7	8	-0.03	-
SC 8	" " " " "	number of profiles p.search	X8	10	-0.55	0.30
SC 9	" " " " "	number of runs per year	X2	11	-0.50	0.25
SC 10	" " " " "	cost of comput. process. /run	X10	11	0.82	0.67
SC 11	" " " " "	cost profile maint. /run	X11	11	0.53	0.29
MC 1	" " " " "	{number of profiles per search number of runs per year}	X8 X2	11	0.67	0.44
MC 2	" " " " "	{cost comp. process. /run cost profile maint. /run}	X10 X11	11	0.87	0.75

SC: simple correlation
MC: multiple correlation

APPENDIX 5 (cont'd.)

Number and type of correlation	Dependent variable Y_i	Independent variable X_i		Number of cases	correlation index	determination index
MC 3	cost per profile per run	number of profiles per search number of runs per year number of records per run	X8 X2 X6	11	0.67	0.44
SC 12	cost per item of output	volume of output per year	X9	10	-0.62	0.39
SC 13	" " " " "	number of records per year	X3	10	-0.41	0.16
SC 14	" " " " "	number of search terms /prof.	X4	9	0.15	0.02
SC 15	" " " " "	number of records per run	X6	10	-0.13	0.02
SC 16	" " " " "	number of search terms per run	X12	9	0.30	0.09
SC 17	" " " " "	volume of output per run	X5	10	-0.19	0.03
SC 18	" " " " "	number of runs per year	X2	10	-0.35	0.12
SC 19	" " " " "	cost comput. proc. /run	X10	10	0.65	0.42
SC 20	" " " " "	cost profile maint. /run	X11	10	0.24	0.05
MC 4	" " " " "	number of records per run number of search terms per run	X6 X12	9	0.71	0.51
MC 5	" " " " "	number of search terms per run volume of output per run	X12 X5	9	0.80	0.64

SC: simple correlation
MC: multiple correlation

APPENDIX 5 (cont'd)

Number and type of correlation	Dependent variable Y_i	Independent variable X_i		Number of cases	correlation index	determination index
MC 6	cost per item of output	number of records per run volume of output per run	X6 X5	10	0.18	0.03
MC 7	" " " " "	cost comput.proc, per run cost of profile maint. /run	X10 X11	10	0.68	0.46
MC 8	" " " " "	cost of profile maint. /run number of search terms /run	X11 X12	9	0.88	0.77
MC 9	" " " " "	cost of comp.proc. /run number of records per run	X10 X6	10	0.71	0.51
SC 21	average number of output p/run	cost of comp.proc. /run	X10	10	0.42	0.18
SC 22	" " " " "	cost of profile maint. /run	X11	10	0.78	0.60
SC 23	" " " " "	number of records per run	X6	9	0.75	0.56
SC 24	" " " " "	number of search terms /run	X12	9	0.75	0.56
MC 10	" " " " "	cost of comp. proc. per run cost of profile maint. /run	X10 X11	10	0.78	0.60
MC 11	" " " " "	number of records per run number of search terms /run	X6 X12	9	0.92	0.84

SC: simple correlation
MC: multiple correlation

APPENDIX 6

APPENDIX 6

Assumptions made for systems 1 and 2 used in the analysis and taken from reference (75):

1. The systems are manual systems based on cards. Although these could be plain filing cards or punched cards; the timings, etc. are based on data actually obtained for an optical coincidence card system (77);
2. 10,000 document capacity cards are used (the annual cost would be about 5% more for 4,000 document capacity cards);
3. Searching takes 2 minutes per set of 10,000 optical coincidence cards;
4. Indexing and punching an average of 10 concepts per document takes 3 minutes;
5. Searching and processing costs are calculated by multiplying times by 7.5p per minute (based on annual salary of £2,700 and overheads);
6. The annual cost of cards, storage and labelling the cards is £240 for 10,000 documents per annum; this is based on J.L. Jolley and Partners Limited prices for two thousand 10,000 document capacity cards and one desk tray (£217) every year for 10,000 documents a year (or five years, if 2,000

documents per annum) plus labour costs for labelling cards, thesaurus maintenance, etc. (approximately 7 hours per annum);

7. That a semi-automatic punch costing £70 is used;

8. Other setting up costs are mainly labour, estimated to be about 2 man months from the data given by Baker (77) and costed at £800;

9. All the above costs are at 1975 prices.

APPENDIX 7

APPENDIX 7

ESTIMATED COSTS FOR SYSTEM 1 AND SYSTEM 2

	(1) 2,000 doc/year	(2) 10,000 doc/year
YEAR 1	£	£
Setting up costs	870	870
Annual materials, etc	60	240
Input labour	450	2,250
TOTAL	1,380	3,360
Cost per search labour	0.15	0.15
AVERAGE COST PER SEARCH		
S:50	27.6	67.3
S:100	13.8	33.7
S:200	7.0	16.9
S:500	2.8	6.9
YEAR 2		
Annual materials, etc	60	240
Input labour	450	2,250
TOTAL	510	2,490
Search labour cost	0.15	0.30
AVERAGE COST PER SEARCH		
S:50	10.3	50.1
S:100	5.2	25.2
S:200	2.7	12.7
S:500	1.2	5.3
YEAR 3		
Annual materials, etc	60	240
Input labour	450	2,250
TOTAL	510	2,490
Search labour cost	0.15	0.45
AVERAGE COST PER SEARCH		
S:50	10.3	50.2
S:100	5.2	25.3
S:200	2.7	12.9
S:500	1.2	5.4

APPENDIX 7 (cont'd)

YEAR 4	(1) 2,000 doc/year	(2) 4,000 doc/year
	£	£
Annual materials,etc	60	240
Input labour	450	2,250
TOTAL	510	2,490
Search labour cost	0.15	0.60
AVERAGE COST PER SEARCH		
S:50	10.3	50.4
S:100	5.2	25.5
S:200	2.7	13.0
S:500	1.2	5.6

YEAR 5	(1) 2,000 doc/year	(2) 4,000 doc/year
Annual materials, etc	60	240
Input labour	450	2,250
TOTAL	510	2,490
Search labour cost	0.15	0.75
AVERAGE COST PER SEARCH		
S:50	10.3	50.5
S:100	5.2	25.6
S:200	2.7	13.2
S:500	1.2	5.7

APPENDIX 8

References

APPENDIX 8

REFERENCES

1. Frisch, R. "Theory of Production", D. Reidel Publishing Co., 1965.

2. Price, D. "Rational Cost Information: Necessary and Obtainable", Special Libraries, 1974, 65, (2), pp.45-57.

3. Wilson, J.H.R. "Costs Budgeting and Economics of Information Processing" in Cuadra, C. (Ed.), Annual Review of Information Science and Technology, American Society for Information Science, Vol.7, 1972, pp.38-67.

4. Bourne, C.P. "Evaluation of Indexing Systems" in Cuadra, C. (Ed.), Annual Review of Information Science and Technology, Interscience Publishers, Vol.1, 1966, pp.171-190.

5. Thorne, R.G. "The Efficiency of Subject Catalogues and the Cost of Information Searches", Journal of Documentation, 1955, 11, (3) pp.130-148.

6. Taube, M. & Associates "Cost as a Measure of Efficiency and Cost of Generic Coding" in Studies in Coordinate Indexing, Documentation Inc., Washington DC, 1956, Vol.3.

7. Montague, Barbara A. "Testing, Comparison and Evaluation of Recall Relevance, and Cost of Coordinating Indexing with Links and Roles", American Documentation, 1965, 16, pp.201-208.

8. Rider, F. "Library Cost Accounting", Library Quarterly, 1936, 6, (4), pp.331-381.

9. Miller, R.A. "Cost Accounting for Libraries: Acquisition and Cataloguing", Library Quarterly, 1937, 7, (4), pp.516-536.

10. Cooper, M.D. "The Economics of Information" in Cuadra, C. (Ed.), Annual Review of Information Science and Technology", American Society for Information Science, Vol.8, 1973, pp.5-40.

11. Spence, M.A. "An Economist's View of Information", in Cuadra C., (Ed.), Annual Review of Information Science and Technology, American Society for Information Science, Vol.9, 1974, pp.57-80.

12. Hindle, M.A., Raper, D. "The Economics of Information", in Williams, M.E. (Ed.), Annual Review of Information Science and Technology, American Society for Information Science, Vol.11, 1976, pp.28-54.

13. Mick, C.K. "Cost Analysis of Information Systems and Services", in Williams, M.E. (Ed.), Annual

Review of Information Science and Technology, American Society for Information Science, Vol. 14, 1979, pp.38-64.

14. "Economic Studies of Library and Information Systems" British Library Research and Development Newsletter, 1975 (September), (5).

15. "Research Priorities 1979-1981: The Approach of the British Library Research and Development Department", Journal of Documentation, 1979, 35, (2), p.143.

16. Bourne, C.P. "Data Collection and Cost Modelling for Library Circulation System", U.S. Office of Education, Bureau of Research, Washington DC, 1970.

17. Price, D.S. "Collecting and Reporting Real Costs of Information Systems", American Society for Information Science, SIG/CBE, 1971.

18. Palmer, D.C. "Measuring Library Output", presented at: Institute of Program Planning Budgeting Systems for Libraries, Wayne State University, Michigan, 1968.

19. Kozumplick, W.C. "A Time and Motion Study on Library Operations", Special Libraries, 1967, 58, (8), pp. 558-588.

20. Lancaster, F.W. "Cost Effectiveness Analysis of Information Retrieval and Dissemination Systems",

Journal of the American Society for Information Science, 1971, 22, (1), pp.12-27.

21. King, D.W., Bryant, E. "The Evaluation of Information Services and Products" Information Resources Press, 1971.

22. Fasana, P.J. "Determining the Cost of Library Automation", Bulletin of the American Library Association, 1967, 61, pp.656-671.

23. Stitleman, L. "Cost Utility Analysis Applied to Library Budgeting", presented at: Institute on Program Planning Budgeting Systems for Libraries, Wayne State University, Michigan, 1968.

24. Swanson, D.R. "Should the Present Methods for Financing Library and Information Services Survive?", in ACM Annual Conference Proceedings, Chicago, August 1971, pp.568-569.

25. Pigou, A.C. "Economics of Welfare", 4th.edn., Macmillan, MacMillan, N.Y., 1960.

26. Durham University "Project for evaluating the Benefits from University Libraries", Durham University, Durham, 1969.

27. Machlup, F. "The Production and Distribution of Knowledge in the United States", Princeton University Press, New Jersey, 1962.

28. Lamberton, D.M. "Introduction", in Lamberton, D.M. (Ed.) Economics of Information and Knowledge, Penguin Modern Economics Readings, Penguin Books Ltd., 1971.

29. Marschak, J. "Economics of Information Systems" in Lamberton, D.M. (Ed.), Economics of Information and Knowledge, Penguin Modern Economics Readings, Penguin Books Ltd., 1971.

30. Marschak, J. "Optimal Symbol Processing - A Problem in Individual and Social Economics", Behavioural Sciences, 1971, 16, (3), pp.202-217.

31. Jenner, R.A. "An Information Version of Pure Competition" in Lamberton, D.M. (Ed.), Economics of Information and Knowledge, Penguin Modern Economics Readings, Penguin Books Ltd., 1971.

32. Stigler, G.J. "The Economics of Information" in Lamberton, D.M. (Ed.), Economics of Information and Knowledge, Penguin Modern Economics Readings, Penguin Books Ltd. 1971.

33. Fischer, G.H. "Cost Considerations in System Analysis", American Elsevier Publishing Co., N.Y., 1971.

34. Winch, D.M. "Analytical Welfare Economics", Penguin Books Inc., Maryland, 1971.

35. California University, Santa Barbara "Final Report of the Findings of the Feasibility Phase", University of California, Library Systems Development Program, California, 1970.

36. Hayamy, Y., Peterson, W. "Social Returns to Public Information Services: Statistical Reporting of U.S. Farm Commodities", American Economic Review, 1972, 62, (1), pp.119-130.

37. Leimkuhler, F.F. "Mathematical Models for Library Systems Analysis", Purdue University, School of Industrial Engineering, Lafayette, Indiana, 1967.

38. Wilkin, A.P., Reynolds, R., Robertson, S.E. "Standard Times for Information Systems: A Method for Data Collection and Analysis", Journal of Documentation, 1972, 28, (2), pp.131-150.

39. Cooper, M.D., "A Cost Model for Evaluating Information Retrieval Systems", Journal of the American Society for Information Science, 1972, 23, (5), pp.306-312.

40. Negus, A.E. "Towards an Effective On Line Reference Retrieval System", Information Storage and Retrieval, 1971, 7, (6), pp.249-270.

41. Dammers, H.F. "Economic Evaluation of Current Awareness System" in Aslib Conference, Paris,

France, 1973, November 20 - 22, Eurim Proceedings, Aslib, 1974, pp.107-124.

42. Dammers, H.F. "Progress in Documentation: The Economics of Computer Based Information Systems, A Review", Journal of Documentation, 1975, 31, (1), pp.38-45.

43. Martin, J. "Resources Research: Aslib R & D and the Future", Aslib Proceedings, 1975, 27, (1), pp.16-21.

44. Hamburg et al "A Systems Approach to Library Management", Journal of Systems Engineering, 1976, 4, (2), pp.117-130.

45. Flowerdew, A.D.J. and Whitehead, C.M.E. "Cost Effectiveness and Cost Benefit Analysis in Information Science", Report to OSTI on Project S1/97/03, OSTI Report No. 5206, London, October 1974.

46. Schipma, P. "Generation and Use of Machine Readable Data Bases" in Cuadra, C. (Ed.), Annual Review of Information Science and Technology, American Society for Information Science, Vol. 10, 1975, pp.237-271.

47. Adams, S., Werdel, J.A. "Cooperation in Information Activities through International Organizations" in Cuadra, C. (Ed.), Annual Review of Information Science and Technology, American Society for

Information Science, Vol.10, 1975, pp.303-356.

48. Vickers, P. "Costs of Mechanized Information Systems", Directorate for Scientific Affairs, OECD, 1959.

49. Ford, G. "Library Automation, Guidelines to Costing", Lancaster, England, OSTI Report 5163.

50. Magson, M.S. "Techniques for the Measurement of Cost Benefit in Libraries", Aslib Proceedings, 1973, 25, (5), pp.164-185.

51. Bommer, M. "Operations Research in Libraries: A Critical Assessment", Journal of the American Society for Information Science, 1975, 26, (3), pp.137-139.

52. Marchant, M.P. "University Library as Economic System", College and Research Libraries, 1975, 36, (6), pp.449-457.

53. Buckland, M.K. et al. "Methodological Problems in Assessing the Overlap between Bibliographical Files and Library Holdings", Information Processing and Management, 1975, August, (11), pp.89-105.

54. Braunstein, Y.M. "An Economic Rationale for Page and Submission Charges by Academic Journals", Journal of The American Society for Information Science, 1977, 28, (6), pp.355-357.

55. Cooper, M.D., "The Economics of Library Size: A Preliminary Inquiry", Library Trends, 1979, 28, (1), pp.63-78.

56. Flowerdew, A.D.J. et al. "Problems in Forecasting the price and demand for On-Line Information Services" in Elton, M. (Ed.) Evaluating New Telecommunications Services, Plenum Press, N.Y., 1978.

57. Gold, S.D. "Allocating the Book Budget: An Economic Model", College and Research Libraries, 1975, 36, (5), pp.397-402.

58. King, D.W. "Pricing Policies in Academic Libraries", Library Trends, 1979, 28, (1), pp.47-62.

59. Lancaster, F.W. "The Measurement and Evaluation of Library Services", Information Resources Press, Washington, 1977.

60. Mason, R.M. "The Economics and Cost Benefit of Analysis Services: The Case of Information Analysis Centres", in Elton, M. (Ed.), Evaluating New Telecommunication Services, Plenum Press, N.Y., 1978.

61. Pratt, G. (Ed.) "Information Economics: Cost and Prices of Machine Readable Information in Europe", Aslib and Eusidic, London, 1976.

62. Rowe, D. "Application of the Theory of the Firm to Library Costing", Australian Library Journal, 1974, 23, (3), pp.108-111.

63. Vickers, P. "Ground Rules for Cost-Effectiveness", Aslib Proceedings, 1976, 28, (6/7), pp.224-229.

64. Zais, H.W. "Economic Modelling: An Aid to the Pricing of Information Services", Journal of the American Society for Information Science, 1977, 28, (2), pp.89-95.

64A. Karen, C., Schwuchow, W. "Economic Aspects of Information Services - Report on a Symposium" Journal of Information Science, 1981, 3, (5), pp.249-251.

65. Bottle, R.T. "A User's Assessment of Awareness Services", Journal of Documentation, 1965, 21, (2), pp.177-189.

66. Boulding, K.E. "The Economics of Knowledge and the Knowledge of Economics", in Lamberton, D.M. (Ed.), Economics of Information and Knowledge, Penguin Modern Economics Readings, Penguin Books Ltd., 1971.

67. Peeters, E. "Couts du traitment automatique de l'information documentaire", Association Belge de la Documentation, Colloque National de la Documentation, Bruxelles, May 1974.

68. Ezekiel, M. "Methods of Correlation and Regression Analysis", John Wiley and Sons, 1959.

69. Turnovsky, S.J. "The Production Flexibility, Price Uncertainty and the Behavior of the Competitive Firm", International Economic Review, 1973, 14, (2), pp. 395-413.

70. Forsund, F.R. "Generalised Farrel Measures of Efficiency: An Application to Milk Processing in Swedish Dairy Plants", The Economic Journal, 1979, 89, pp.294-315.

71. Vicent, D.P. et al. "The Estimation of Supply Response in Australian Agriculture", International Economic Review, 1980, 21, (1), pp.221-242.

72. Eldor, D. et al. "Production Cost Elasticity in Products and Factors Market - Case of Telecommunications", Journal of Economic Business, 1979, 31, (2), 84-89.

73. Gottscha, P.T. "Comparation of Marginal Productivity and Earnings by Occupation", Industrial Labour Relations, 1978, 31, (3), pp.368-378.

74. Urquhart, D.J. "Economic Analysis of Information Services" Journal of Documentation, 1976, 32, (2), pp.123-125.

75. Bottle, R.T. "Making the most of Manual Systems", Information for the Water Industry, Reading Conference Proceedings, March 1976, Water Research Centre 1977, pp.217-226.

76. Schneider, E. "Teoria della Produzione" Casa Editrice Ambrosiana, Milan, 1942.

77. Baker, K.J. "Unit concept co-ordinate indexing: The cost of setting up and operating a system", Northern Aslib Bulletin, 1966, 4, (11), pp.3-10.