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ABSTRACT

As a part of the program of the Organization for Economic Cooperation and Development (OECD) Information Policy Group, this report is intended to contribute to discussions of policy formulation in the field of information. The author presents a quantitative retrospect of the group of scientific literature and forecasts the future growth of the literature by extrapolation. A scenario technique based on Delphi surveys is used to predict automation in the knowledge transfer process. The morphology of the growth of information is examined, and a general diagnosis and recommendations are offered. In the author's opinion, the problems of information transfer have been largely underestimated. He predicts a great technological innovation and revolutionary change from 1980-90 will have a profound impact on society and insists upon an immediate effort to set objectives and priorities. He recommends and provides guidelines for setting up international machinery for monitoring and assessment and an Institute for Information Science and Technology for training purposes. The OECD is encouraged to take the lead in the formulation of policies, survey research, and technological coordination. (JG)

INFORMATION IN 1985

A Forecasting Study of Information Needs and Resources

by Georges Anderla

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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The Organisation for Economic Co-operation and Development (OECD) was set up under a Convention signed in Paris on 14th December, 1960, which provides that the OECD shall promote policies designed :

- *to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;*
- *to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development;*
- *to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.*

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* * *

This report was prepared by Dr. Georges Anderla, Professor at the Institut d'Etudes Politiques and the University of Paris, at the request of the OECD Directorate of Scientific Affairs. It forms part of the programme of activities of the OECD Information Policy Group and is intended to contribute to discussions of policy formulation in the field of information.

The opinions expressed in the report are the responsibility of the author and are not necessarily those of the OECD.

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INTRODUCTION

OBJECTIVES AND GENERAL OUTLINE

The primary purpose of this study is to estimate the supply of, and above all the demand for, scientific and technical information; its secondary objective is to make a long-term assessment of qualitative and quantitative requirements for information specialists. In both instances, of course, future technical developments, as far as they can be foreseen, must be taken into account.

At the same time, like most work sponsored by the OECD, its aim is to identify significant criteria for defining a policy - in this case an information policy, which is greatly needed in all OECD countries.

The benefit to be derived from a set of long-range forecasts is evident. However, their ultimate usefulness should be judged by the results obtained by the author by means of various research and forecasting techniques. Readers wishing to gain a rapid picture of the main features of the report should turn to Summary table 6, page 122, which recapitulates the principal conclusions and indicates the methods used and the reliability of the quantitative and qualitative forecasts they have produced. It is followed by a general diagnosis and a number of concrete policy recommendations.

The detailed forecasts are developed and discussed step by step in the main body of the report, particularly in Chapters 2 to 4.

THE CONCEPT OF INFORMATION TRANSFER

At the outset a number of background comments are called for regarding certain basic problems and certain questions of approach and procedure. It would seem important to begin by defining precisely what is meant by scientific and technical information.

For some time, opinion among experts and political and administrative authorities has, in the main, crystallised into three different, not to say conflicting, concepts. The generation and utilisation of scientific and technical information, taken in the narrow sense, is confined to the general scientific community, including engineers, technical specialists, physicians and other practitioners. In other words, this traditional approach regards information as both an output and input of research (fundamental and applied) and development.

A broader view, which might be called socio-cultural, holds that information and transferable knowledge are one and the same thing. On this basis all information transfer should be defined as a transfer of knowledge not merely serving the scientific community, but a whole range of activities: training, education, culture, mass media, medicine and possibly certain tertiary services.

A third school of thought which is rapidly gaining ground regards information as a resource, a resource as fundamental as energy or matter which affect all human activity, and as an indispensable, irreplaceable link between intellectual and material activities. This overall concept of information is bound of course to lead to one conclusion, namely that information must be at the service of the whole community, i.e. particular institutions and social groups as well as society and individuals in general.

We shall not, at this stage, take sides in this controversy but prefer instead to examine these three approaches in turn, since each undoubtedly contains a grain of truth and a certain measure of practical utility. The Summary table 6, page 122, to which we have referred, will then enable us to compare these three viewpoints and, in particular, the long-range forecasts relevant to each.

It will then be realised that the three hypotheses lead to conclusions which, far from being contradictory, are compatible and even complementary.

THE PROBLEM OF MEASURING INFORMATION

Any analysis for scientific purposes and a fortiori any rational forecasting exercise must be based on a system of measurement and reference values. We will, therefore, describe those on which this forecasting study is based.

Notions such as information and information transfer, like all complex and multiform phenomena, cannot be defined in their entirety, nor can their diversity be assessed, by direct means. Their real nature can be grasped only through certain indirect indicators or quantitative indices and through a series of qualitative attributes.

Similarly the demand, supply and needs of information can only be evaluated by means of partial measurements relating to quantity, frequency, rates of increase, etc. and in terms of non-quantifiable characteristics such as the content or nature of the information requested or supplied, types of seeker and user, quality of service, conditions of access and so on. Soundness of the forecasts will largely depend on the validity and representativity of the indices and attributes adopted.

In particular the choice of units of measurement, as always in such cases, presents difficult problems. To compensate for the arbitrary nature of this choice we shall use a whole series of indices instead of just one or two. For instance, when evaluating the increase in the volume of scientific information over time, we shall consider not only the number of technical articles that are published but several other indices as well. The qualitative aspects of information demand will also be examined as exhaustively as possible.

But this approach has its pitfalls. Numerous indices and attributes may well subject our analyses and forecasts to a number of spurious correlations of a familiar kind, such as the inevitable correlation between total income and total consumption. This danger is all the greater in the present case in that the producers of articles and other scientific writings are at the same time, to a large extent, the users of this literature.

In fact, the aggregate demand often tends to become confused with the total supply of information and the tangle is not easy to unravel. In practice, most of the figures available relate to supply, i.e. articles, books and technical reports which have appeared. But we shall sometimes be compelled to use such data for a quantitative estimate of "demand" and "needs". Readers are, therefore, forewarned of this substitution and their attention is drawn to the implications.

This drawback will, of course, cease to apply when the qualitative aspects of information in Chapter 4 are dealt with. A systematic analysis will show that compared to the supply of information and the relatively restricted range of services it comprises, the demand for information forms an extremely broad spectrum of interlinked requirements.

BRIEF SURVEY OF METHODS USED

The nature of the problem of course determines the choice of method. Since information transfer is a many-facetted process, its study requires the use of several methods, either concurrently or successively. Moreover, for forecasting purposes it is always better to use several approaches - another reason why a variety of methods must be employed.

Those we shall use range from extrapolation, through scenario-writing, to morphological analysis. To some extent we shall also use traditional correlation and, of course, various mathematical models for checking the assumed direction of a trend or for postulating future trends.

We shall also add some more original tools. For instance, we shall consider to what extent the cobweb theorem can make it easier to understand the dynamics of information transfer, and more especially explain the independent nature and spontaneous action of a built-in accelerating mechanism whose existence is beyond doubt.

As a preliminary, we thought it would be useful to devote an initial chapter to a brief retrospect both in order to illustrate past and present trends and to give a historical dimension and perspective to the forward looking views of the chapters that follow (2, 3 and 4).

All the methods used come under the heading of exploratory forecasting whose central feature is that it starts out from a relatively well-established set of facts in order to evaluate future possibilities with some degree of reliability.

The use of normative forecasting methods, on the other hand, must be largely ruled out. Normative forecasting consists in first defining objectives and missions, and even actions to be undertaken to achieve these objectives, and in working back from this point to the present situation. But such objectives can only be determined when a reasoned choice of information policy has been made and this is precisely what is lacking - for reasons which are easy to explain. The makers of information policy must have many sound criteria on which to base their judgment; in particular they need an exploratory view of future possibilities. Perhaps this study will provide a few new and useful factors for the purpose.

THE LIMITATIONS OF THIS STUDY

Although no specific horizon year was set initially, early investigation showed the asymmetric dangers of too short a perspective (say up to 1980) and forecasts over too long a time (say up to the year 2000).

There are very good grounds for supposing that there will be a clustering of technological innovations in hardware, software, peripherals and telecommunications midway between 1980 and 1990. Coupled with the invention of new and powerful tools of analysis, indexing and retrospective search, these events will almost certainly revolutionise information, the transfer of which may well by that time be organised on an industrial scale.

It was, therefore, finally decided that our exploration of future patterns should cover roughly the next 15 years. This time frame is by no means rigid, and when the subject at issue so requires we shall venture - exercising the necessary caution - beyond 1985-1987. In other cases, we shall be concerned more especially with the turning point, that is 1978-1980, which will probably mark the first wave of automated applications of information transfer on a massive scale.

There is another limitation which needs pointing out. In a 15-year perspective, it is impossible to forecast the future needs for scientific and technical information specialists in isolation, for instance by simple extrapolation of staff and work forces currently employed. Such requirements will, in fact, depend on the general demand and need for information in the years to come. The only way to evaluate them is by inference, on the basis of foreseeable trends in this demand, i.e. allowing for technological possibilities.

Even so, our estimates with regard to highly qualified personnel for the next 15 years will necessarily, at this stage, be relatively rough and, above all, global estimates. More detailed forecasts clearly cannot be prepared without an exhaustive study of integrated information networks first. These changes in the pattern of supply will affect, quite as much as the demand, future needs for information specialists.

Chapter 1

A QUANTITATIVE RETROSPECT

The spectacular and extraordinarily rapid development of scientific discoveries and knowledge in modern times has inevitably caused an unprecedented accumulation and congestion of information.

Hence the need to study scientific and technical information and its dynamics, especially from the standpoint of the volume of data and documents to be collected, stored and redistributed. So vast are these physical problems that attention has focused on the quantitative aspects of information often to the detriment of an understanding of its qualitative aspects.

In particular, a number of authors have contributed to the belief:

i) that for two centuries or more, the volume of scientific knowledge and consequently the volume of scientific information available has increased in geometric progression;

ii) that, for all disciplines and all methods of recording, this meant that the volume doubled every 10 or 15 years, or grew even more rapidly in some cases, and;

iii) that this exponential growth was bound, sooner or later, to reach a ceiling, or taper off, and in fact was already slowing down.

In the light of the most recent facts it would appear essential to reconsider these three assumptions very carefully. This will be the purpose of this first chapter. The main subject, i.e. the vast field of forecasting, will be dealt with from Chapter 2 onwards.

1.1 THE GROWTH OF SCIENTIFIC LITERATURE

Since the appearance of the first two scientific journals in the 17th century, the <u>Journal des sçavants</u> in Paris and the <u>Philosophical Transactions of the Royal Society</u> in London, in other words in the three centuries between about 1660 and 1960, all indicators of the volume of science have increased by a factor of about one million(1). By the middle of the 18th century there were still only about 10 scientific journals in existence; around 1800 there were 100, around 1850 1,000, and at the beginning of the present century about 10,000(2).

As far as the present-day period is concerned, estimates of the number of scientific journals appearing more or less regularly throughout the world is between 30,000 and 100,000. According to a no longer recent source(3) 50,000 periodicals of this kind have been founded and 30,000 of these are still surviving. But these data seem to be incomplete. An OECD report(4) published in 1968 quotes a figure of 35,000 scientific journals for 1963, including 6,200 American publications, whereas UNESCO(5) puts the figure at somewhere between 50,000 and 70,000. Other authorities(6) lean towards the even higher figure of 100,000 scientific and technical periodicals.

By the first half of the 19th century, new scientific journals were being published at such a rate that, as from about 1830, specialist services began to be set up for bibliographic indexing and/or abstracting. These services also grew exponentially, increasing tenfold every 50 years(7). More than 1,800 specialised organisations were counted in a recent census(8).

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1) de Solla Price, Derek J., Little Science, Big Science, New York, Columbia University Press, 1963, p. 9.

2) Garvey, William D. and Bertita E. Compton, "The Flood and How to Survive It", The Johns Hopkins Magazine, Fall 1967, p. 3.

3) de Solla Price, Derek J., Little Science, Big Science, p. 8. See also U.S. National Academy of Science, Scientific and Technical Communication, 1969, p. 9.

4) Reviews of National Science Policy - United States, OECD, Paris, 1968, pp. 225-41.

5) UNESCO, UNISIST. Study Report on the Feasibility of a World Science Information System, 1971, Section 1.3.

6) Earl Mountbatten, "Controlling the Information Explosion", Radio & Electronic Engineer, No. 31, April 1966, pp. 195-208. See also Hammer, Donald P., "National Information Issues and Trends", in Annual Review of Information Science and Technology (Editor: Carlos A. Cuadra), Vol. 2, John Wiley and Sons, Inc., 1967, p. 387.

7) Garvey William D. and Bertita E. Compton, "The Flood and How to Survive It", op. cit., p. 4.

8) Winters, A.A., "Besoins des utilisateurs dans un système d'information", (Requirements of users in an information system), Euro Spectra, Vol. 11, 1972, p. 30.

All modes of expression seem to have been involved in this "explosion". Proceedings of meetings, technical reports and pre-prints have also been marked by more or less regular exponential growth.

What is more, the trend is not limited to fundamental or pure science. Exactly the same pattern is found, for example, in the activities of practising engineers who, particularly in the United States, have doubled their output of literature in six years. A case in point is civil engineering where more than 30,000 pages spread over 42 specialised periodicals appeared in 1966, compared with 3,000 pages of technical articles in three specialised journals in 1946(1).

The public sector is also very much in the picture. Thus the scientific and technical services of the United States Government alone publish some 70,000 to 80,000 technical reports every year(2).

The learned societies have followed the same trend; the number of international scientific congresses has increased fourfold in 20 years, rising from 1,000 in 1950, to 2,000 in 1960 and to 3,500 in 1968(3).

Though these examples are selected somewhat at random and are certainly not new, the conclusions they suggest are, in fact, largely original:

i) In all the cases mentioned, growth follows a geometric progression, the curve being exponential.

ii) The growth rates observed however vary considerably, the lowest yearly figure being 3.5 per cent and the highest 14.4 per cent.

iii) The lowest rates relate to the longest series (covering 300 and 140 years respectively), namely the number of scientific periodicals published at various periods and the number of specialist organisations involved in bibliographic indexing and abstracting. In the case of scientific journals

1) Garvey, Williams D. and Bertita E. Compton, "The Flood and How to Survive It", op. cit., p. 4.

2) Reviews of National Science Policy - United States, OECD, op. cit.

3) McHale, John, "The Changing Information Environment: A Selective Topography", in Information Technology: Some Critical Implications for Decision-Makers, 1971-1990, p. 44.

the annual growth rate has been 3.5 per cent, 3.7 per cent or 3.9 per cent, depending on whether the number published at the present time is taken as 30,000, 50,000 or 100,000. The growth rate for indexing and abstracting organisations has been 5.5 per cent a year.

iv) On the other hand, the short and recent series, relating to the number of articles produced by engineers, the number of civil engineering journals and the number of articles they contain, show a very much higher growth rate: 12.3 per cent, 14.4 per cent and 12.2 per cent respectively.

v) The growth rate in the number of international, scientific and technical congresses has been 7.2 per cent and thus lies somewhere between these two extremes.

vi) A further possibility, though at the moment this is pure hypothesis, is that for the last 20 or 30 years technical information has become available at a faster rate than scientific information.

1.2 CUMULATIVE INDICES OF QUANTITY

What is the present situation? In the early 1970s altogether 2,000,000 scientific writings of all kinds would appear to be issued each year(1), or in other words, 6,000 to 7,000 articles and reports per working day.

This recent estimate by the highly respected National Academy of Science in the United States somewhat eclipses the figure advanced only a few years earlier by de Solla Price(2) whose yearly count was only 600,000 magazine articles, although it is true that this did not include technical reports and other recorded material.

1) "Already the figures have become staggering - roughly 40,000 research papers a year in physics, several times that number in chemistry, biology and agriculture, even more in medicine and perhaps as many as 2,000,000 in all fields of science and technology taken together". United States, National Academy of Science, Scientific and Technical Communications, 1969, op. cit., p. 9.

2) de Solla Price, Derek J., Little Science, Big Science, op. cit., p. 79.

A cross-check with three other estimates tends to confirm the higher assumption. According to a first source(1), scientific and technical articles and reports amount at the moment to 250 million pages. A second source(2) gives an even higher figure: 150,000 pages per day, i.e. 450 to 500 million pages per year. A third source expresses scientific and technical literary output in a different way, by assessing it at some 20 million words per day(3).

To this current output must be added, of course, the stock already accumulated. This has been assessed at 10 trillion (10^{13}) alphanumeric characters(4). This figure, extraordinary in itself, is said to represent the quantity of scientific and technical knowledge recorded in all forms from the birth of science to the mid-1960s.

This total - which relates to all of what are called the primary sources of information - has three main constituents: first the articles in journals available to the public, secondly books and various types of publication ranging from brochures and offprints to manuals and encyclopaedias, and lastly a wide variety of communications in the form of technical reports, records of meetings, preprints, etc., of restricted circulation.

For this last category our information is very incomplete and in most cases cannot be checked. It is in any case difficult to ascertain the quantity of such papers. All one can say with any degree of certainty is that private or semi-public scientific and technical texts are increasing at an extremely fast rate. To give one example only, it is estimated that some 2 million scientists, technicians and specialists "actively" participate each year in international congresses alone(5); if national meetings and conferences are taken into account, probably more than 5 million

1) Leimkuhler, Ferdinand F. and Anthony E. Neville, "The Uncertain Future of the Library", The Johns Hopkins Magazine, Fall 1967, p. 15.

2) Saunders, W.L., "Economic Success: the Contribution of the Information Scientist", The Information Scientist, Vol. 2, No. 3, 1969, pp. 118-19.

3) Murray, Herbert, Jr., Methods for Satisfying the Needs of the Scientist and the Engineer for Scientific and Technical Information, Redstone Scientific Information Center, Redstone Arsenal, Alabama, 11th January, 1966, p. 19.

4) Licklider, J.C.R., "A Crux in Scientific and Technical Communication", American Psychologist, No. 21, November, 1966, pp. 1044-51.

5) McHale, John, "The Changing Information Environment - A Selective Topography", in Information Technology - Some Critical Implications for Decision-Makers, 1971-1990, p. 44.

individuals contribute in one way or another to the creation and distribution of scientific and technical information in one year.

The cumulative world stock of journal articles has been estimated in one case at 6 million and in another at 10 million titles for all scientific disciplines put together(1). Both these figures are too low, which becomes obvious when comparing them with the number of articles produced during any one recent year, or with the number of articles registered by any of the large scale automated information systems. The ENDS system in Luxembourg, for example, has listed no fewer than 1.5 million articles in the field of nuclear energy alone, and NASA and ESRO quote similar figures.

It is therefore likely that the present-day world stock of scientific and technical articles numbers at least some 20 to 30 million titles.

As far as books are concerned, it has been estimated that the number of volumes contained in an imaginary world library, excluding all other primary sources, is 100 million, counting each title only once(2). On the other hand, we have no idea of the respective shares of science and technology in this total stock.

It seems hardly possible to conceive the vastness of the physical problems of recording and storing all this literature, quite apart from the problems of producing and disseminating it. If all printed works could be reproduced in full on a computer, typed on a single line they would cover 125,000 million miles, and to record them electronically at present prices would come to some 1,000 billion (10^{12}) dollars. Probably as much, if not more, would be needed to store periodic and non-periodic scientific literature in magnetic memories.

Let us suppose, again, that it is decided to draw up a universal catalogue of all books. Assuming that each title would appear, with the name of the author, the publisher and the date of publication, on only five lists (this would seem to be a minimum) the result would be 1,000 million lines of text or the equivalent of 10,000 volumes of the size of a large dictionary(3).

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1) de Solla Price, Derek J., Little Science, Big Science, op. cit., pp. 8 and 79.

2) Figure given by Meetham, Roger, Informatique et documentation (translated from English). Larousse, Paris (Collection "Techniques d'aujourd'hui"), 1971, p. 70.

3) Ibid.

These are some of the orders of magnitude that have to be reckoned with.

1.3 RECENT TRENDS TOWARDS ACCELERATION

The proliferation of scientific literature appearing throughout the world has quite naturally prompted a truism on the part of observers and specialists, which is that this escalation could not follow indefinitely a compound-interest curve, i.e. the exponential function (Diagram 1, Figure a).

The very high level that had been reached for some time led them to think that the inevitable slow-down would take the form of a logistic curve (Figure b), which initially grows at an exponential rate but then flattens off, the point at which the slope changes being located halfway between the base representing the first stammerings of science and the upper asymptote representing a kind of absolute limit. Since the curve by definition is symmetric, the steep growth at the start would be matched by an increasingly slower growth in the second stage(1).

The delicate problem is obviously to identify this point where the curve changes and to locate it in time. The enormous accumulated quantities, together with the extremely high rate of growth - from 8 to 10 per cent each year - appeared to justify the opinion generally held in the early 1960s, and even to this day, that we have already, without knowing it, entered the deceleration phase.

In 1963, for example, de Solla Price(2) wrote: "... saturation is ultimately inevitable... We now maintain that it may already have arrived," and a few lines earlier: "I will suggest that at some time, undetermined as yet but probably during the 1940s or 1950s, we passed through the mid-period in general logistic growth of science's body politic".

Today it is absolutely certain that these forecasts, repeated without number and echoed almost universally, have failed to materialise, at any rate so far. Table 1 shows the number of

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1) These could legitimately be called mathematical models. We will revert to this point in Section 4.2.

2) de Solla Price, Derek J., Little Science, Big Science, op cit., p. 31.

Diagram 1

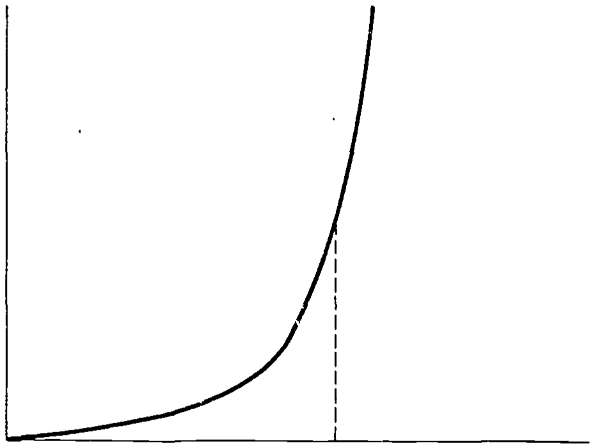

Fig. a. COMPOUND INTEREST
OR EXPONENTIAL CURVE

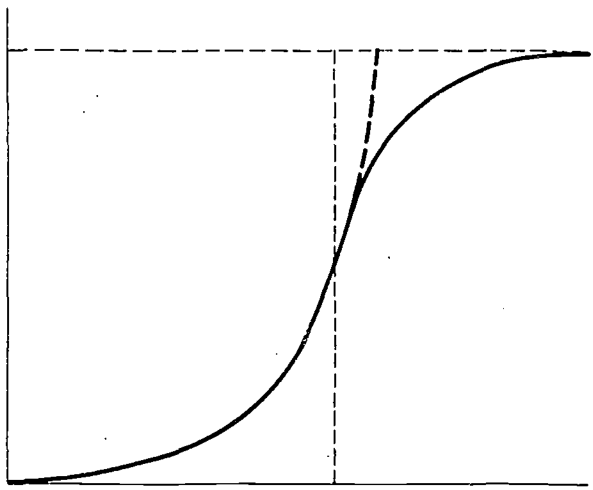

Fig. b. LOGISTIC CURVE
OR EXPONENTIAL GROWTH
FOLLOWED BY SATURATION

abstracts published between 1957 and 1971 for 19 scientific disciplines(1).

In total, this literary output increased by nearly two and a half times in the ten years between 1957 and 1967. The annual growth rate during this period, therefore, was 9.5 per cent. But in the fourteen years from 1957 to 1971 the volume increased more than fourfold, the annual growth rate being 10.6 per cent. This points to an escalation in growth rather than the predicted reverse.

Table 1 is instructive in other ways. If we confine ourselves to the eleven disciplines contained in the 1957 statistics, the growth rate for the fourteen years to 1972 is 9.2 to 9.3 per cent per annum, in other words the quantity doubles in slightly under eight years. The effect of the new disciplines is to increase the growth rate, the volume in this case doubling in slightly less than seven years(2). The exact difference is thirteen months.

Here - and to our knowledge for the first time - we have a measure, however, approximate, of the quantitative effect of the familiar tendency for modern science to diversify and sub-divide into an increasingly large number of disciplines(3).

To conclude, the least that can be said is that this continual diversification in science will delay the moment at which some slowing down might occur in the quantitative expansion of information. For the time being, to judge from the most recent figures, it is contributing significantly to escalation.

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1) The figures given in Table 1 may be compared with the estimates given in the March 1966 issue of Scientific Research according to which 658,000 "significant" documents were generated in 1961 and included in the world's technical literature. In 1965, the figure had risen to 900,500 and by 1970 it was expected to reach 1,143,000. Figures quoted from Jantsch, Erich, Technological Forecasting in Perspective, OECD, 1968, p. 146.

2) The precise figures are seven years and eleven months in the first case and six years and ten months in the second, making a difference of thirteen months.

3) Cf. "... the scope of science and technology is itself increasing" and leading to "the splitting-up of science into sub-disciplines". UNESCO, UNISIST, Report on the Feasibility of a World Science Information System, 1971, op. cit., Section 1.3

Table 1

STATISTICS REGARDING SCIENTIFIC ABSTRACTS
APPEARING IN 19 SPECIALIST JOURNALS

	1957	1967	1968	1969	1970	Estimate 1971
Abstracts of Photographic Science Engineering Literature	-	3.593	3.085	2,665	6.674	7.200
American Petroleum Institute	-	29,000	78,800	32,000	40,000	40 000
Applied Mechanics Reviews	4,245	8,802	9.426	10,000	10.030	10.300
Biological Abstracts	40,061	125,026(2)	212,000(3)	220,010(3)	230.025(3)	230,000(3)
Chemical Abstracts	101,027	239,481(2)	251,984(4)	282,503(4)	309,742(4)	320,800(4)
Computer and Control Abstracts (IEEE INSPEC)	-	6,205	7,311(5)	13,026(5)	22,591(5)	23,000(5)
Electrical and Electronics Abstracts (IEEE INSPEC)	6,451	24,039	30,438(5)	25.795(5)	39.927(5)	40.000(5)
Engineering Index Monthly	26,300	56,560	61,231	56,000	66,000	77,000
Esso Research and Engineering Co.	25,000	10,500(6)	5,300(6)	3,200(6)	3,000(6)	2.000
GEO(1)-REF (Bibliography and Index of Geology AGI)	-	11.450	17,029	27 557	35,000	50.000
Information Science Abstracts (DAI)	-	1,327	1,564	2,638	3.100	4,000
Mathematical Reviews (AMatS)	9,200	17,141	15,179	14,135	18,211	17,000
Medical Documentation Service	-	1,692	1,901	3,102	3,425	4,000
Metals Abstracts (ASM)	8,219	27,800	23,007	25,011	24,255	25,000
Meteorological and Geoastrophysical Abstracts (AMetS)	5,000	9,000	9,269	9,500	10,244	10,000
National Information System for Physics and Astronomy (AIP)	-	-	-	20,000	20,000	25.000
Oral Research Abstracts (ADA)	-	6,631	7,256	7,180	7.289	7.300
Physics Abstracts (INSPEC)(7)	10,001	40,788	50,477	49,619	79,830	80,000
Psychological Abstracts (APA)	9,074	17,202	19,586	18,069	21,722	23,000
Total	244,578	606,187	756,743	822,309	951,065	1,005,600

1) Member services, (90) National Federation of Science Abstracting and Indexing Services; table reproduced with permission of NFSAIS; from *NFSAIS Newsletter (88)*.

2) Major publication only, does not include subsidiary publications.

3) Includes Biological Abstracts and Bio Research Index.

4) These data include duplicate patents referenced to the abstract in Chemical Abstracts through the CA Patent Concordance.

5) The Institute of Electrical and Electronics Engineers became joint publishers with INSPEC (Institution of Electrical Engineers, London) of Electrical & Electronics Abstracts in 1968 and of Computer and Control Abstracts in 1969 (formerly Control Abstracts).

6) Decreases over the years have resulted from shifts in internal publications to equivalent bulletins published outside, chiefly by the American Petroleum Institute.

7) AIP markets Physics Abstracts in U.S.A.

Source: Annual Review of Information Science and Technology, Vol. 6, 1971, British Encyclopaedia, Chicago, Ill. p. 249.

1.4 THE MULTIPLICITY OF SOURCES AND AUTHORS

The accumulation of enormous quantities of information, aggravated by the accelerating pace of its production, is related to the increase in the number of people with scientific and technical qualifications. Clearly the scientists, technologists and their assistants, turned out by our universities and institutes at an accelerating rate, are - to an extent which remains to be determined - the primary source of knowledge and therefore of continually renewed information.

We shall attempt briefly to study this role of theoretical and practical scientists in the creation of scientific and technical information and to evaluate it in quantitative terms. The task is not easy, a major obstacle being the absence of sufficiently reliable and accurate figures. We have shown statistics regarding the volume of information produced to be unreliable, but estimates regarding the number of scientists and technical specialists are frankly suspect.

In the United States alone, according to a book greatly in vogue(1), the number of people with scientific and technical degrees of all kinds has doubled every ten years and increased tenfold every fifteen years, the figures being about 1,000 in 1800, 10,000 in 1850, 100,000 in 1900 and at least a million around 1960(2).

However, the same figures have also been quoted(3) to illustrate the growth, in this case, of the world population of scientists and engineers with university or post-graduate degrees. The total number of these in the world is said to have reached one million in 1950, compared with 100,000 at the beginning of the century and only 10,000 at the middle of the 19th century.

Like all amalgams, comparisons of this type have a large measure of sophistry, as can easily be shown. Let us begin by looking at the difference between two indices which supposedly measure the growth in our knowledge, namely the number of scientific journals in existence at various periods and the number of

1) de Solla Price, Derek J., Little Science, Big Science, op. cit., pp. 8 and 20.

2) Equivalent to a net growth rate of 9.6 per cent per annum.

3) From Reily, Philip K., Proceedings of Information Technology Conference, 20th-21st June, 1968, San Juan, Puerto Rico, p. 2. See also UNESCO, UNISIST. Study Report on the Feasibility of a World Science Information System, op. cit., Section 1.3

articles appearing in these same publications. Let us assume that there are 100 journals to start with and that this number increases regularly, i.e. exponentially, by 10 per cent each year. At the end of 10 years there will therefore be 259 journals if none of them has dropped out in the meantime.

Let us also assume that in the first year 10,000 articles are published. Applying the same growth rate of 10 per cent a year, 25,937 articles should appear during the 10th year, in addition of course, to all the articles published previously, the cumulative total for the 10 years being 185,307 articles. These 25,937 recent articles would therefore account for 14.3 per cent of the total stock of knowledge.

It is clear that the rates expressing the same upward movement will be completely different depending on which of these two series we base our arguments and whether the reference point is the base year, the terminal year, or the accumulated stocks. Failing this clarification, statisticians and forecasters may, in fact, be comparing series which are not comparable.

A further factor, in the case of increases in the active population or in certain categories, is the effect of ageing and therefore of the partial renewal of manpower. If the number of scientists is to increase at the rate mentioned above, i.e. 9.6 per cent net a year, this would imply a gross growth rate of some 13 to 14 per cent to allow for average active lifetime.

These reflections are directly applicable to the problem of the part played by scientists and technical specialists, as authors, in the creation of new information. On the basis of the stock of articles accumulated before 1960, i.e. about 10 million titles(1) and of an average output of 3.5 articles per author, it can be "deduced" that the total number of authors throughout the ages amounts to 3 million, of whom 2.5 million would still be alive(2).

But this estimate becomes untenable when the figure of 2.5 million living authors is compared with the number of articles and other writings currently appearing throughout the world, i.e. at the very least 1.5 million, and more probably 2 million titles a year(3).

1) See 1.2 above.

2) de Solla Price, Derek J., Little Science, Big Science, op. cit., pp. 8, 48 and 79.

3) See 1.2 above.

If these figures are to be consistent, it would be necessary, in order to maintain the present rate of publication, either that every author write one article or other paper every 15 to 18 months, though this seems out of the question; or else that a large number of journals shortly disappear for lack of authors, though this again is contradicted by the present trend towards further escalation.

The theory of an increase in output per author, in terms of articles and other papers, is admittedly not improbable but it would fall short of what is needed to bridge the enormous gap between the assumed number of authors and the number of articles published, which after all is known with more certainty.

This leaves a last possibility, which is also the most reasonable. It is undeniable that categories of authors other than pure scientists nowadays play a major role in the dissemination of new information. In the first place there are the economists, demographers, lawyers, sociologists, psychologists, geographers, pedagogues and other social scientists who are not generally included in the scientific population for the purpose of statistics. In the second place, it is likely that a considerable and no doubt increasing share of the volume of information produced comes from engineers, technicians and practitioners in various disciplines and at various levels and that, in fact, technical information at the moment is increasing at a faster rate than scientific information(1).

By combining the various hypotheses we may estimate roughly but realistically that a minimum of about 10 to 12 million people are involved at the present time in creating and disseminating scientific and technical information in all its forms.

1.5 EXPANSION IN DOCUMENTATION ACTIVITIES

It would be interesting to be able to establish precisely to what extent the trends noted in the production of scientific and technical literature are reflected in its storage and utilisation.

Unfortunately, this question defies analysis in any depth since the information available is not sufficiently full, detailed or comparable. However, since this twofold problem of storage and redistribution is extremely important, we have endeavoured to compile a number of data which, despite their fragmentary nature,

1) This would appear to confirm the possibility suggested at the end of 1.1.

provide some indication of the growth of the services and organisations performing these functions and of the expansion in their activities. Needless to say that, since the indicators available are, as a rule, indirect and partial, any conclusions which they appear to support should be interpreted with caution.

As the number of general or scientific libraries existing at various periods is unknown, we might, as a first approximation, consider the growth of universities, since obviously there is no university without a library. Since Cairo University was founded in 950 A.D. the number of higher education establishments has increased at a rate which follows a more or less exponential curve(1) and which in the last 20 years - as a result of the very many new establishments set up throughout the world - has even tended to increase.

The growth in the analysis centres in the United States is another example of exponential growth. Twelve thousand were counted in 1966 but, significantly, half of them were of recent date, having been set up since 1950(2). Their total number has therefore doubled within the space of 16 years, an annual growth rate of about 4.5 per cent.

The American non-profit making research institutes, like the Battelle Memorial Institute or the Stanford Research Institute, are well known for the high quality of their information and documentation services on which their industrial and scientific research and forecasting work is based. Measured in terms of the cost of their research, their activity has increased from $1.9 million in 1940 to $23.3 million in 1950, $105.9 million in 1960 and $218 million in 1965(3). Here again, growth was exponential and at the extraordinary rate of nearly 21 per cent per annum.

The Johns Hopkins University was founded in 1876. By 1900 it had no more than 100,000 books and ranked tenth among American university libraries. In 1970 it had over 1½ million volumes

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1) de Solla Price, Derek J., Science Since Babylon. Yale University Press, New Haven, 1961. The statistical series used by the author of this work did not go beyond 1959-1960. We have been able to bring the series up to date and thus extend the relevant curve up to 1970.

2) Wasserman, Paul and Evelyn Daniel, "Library and Information Center Management", in Annual Review of Information Science and Technology, Vol. 4, 1969, p. 408.

3) The French Commercial Counsellor, Washington, D.C. writing in Bulletin d'informations économiques, November-December, 1966. It is true that this spectacular geometric progression in the growth of the American research institutes was followed by a levelling-off period but we have no comparative statistics for this.

although it had dropped to twentieth place(1). The slow increase between 1876 and 1900 was followed by an exponential growth between 1900 and 1970 at a rate of 3.9 per cent per annum.

Meanwhile, the 85 main American universities were doubling the number of books in their libraries every 17 years, an annual growth rate of 4.1 per cent. The difference between 3.9 per cent and 4.1 per cent may seem slight and yet it effectively relegated the Johns Hopkins library to a much lower rank.

At the moment this library is adding over 100,000 books to its collections each year and, by 1976, its centenary year, it is expected to have a total of 2½ million volumes. Its present and anticipated growth rate is therefore 8.8 per cent per annum, in other words its size would double every nine years.

Industry is faced with similar problems due to the proliferation of scientific and technical information. The Shell laboratories at Sittingbourne in Great Britain maintain an index covering 2 million biochemical tests carried out by these laboratories and analyse more than one million pages of scientific documents every year from internal and external sources. This is obviously only one example out of thousands of similar ones which may be even more serious, in the case of multinational companies, for instance(2).

1.6 CORRELATION BETWEEN SUPPLY AND UTILISATION

Of the three phases of the documentation cycle - production, storage and utilisation - the last one has undoubtedly been the least understood. And yet real demand, or effective utilisation, is the only unchallengeable yardstick of the utility of both the information produced and the documentation compiled by specialised services and, incidentally, of the efficiency of these services.

Many incorrect conclusions have been broadcast on this subject, often based on correct premises, and it is important that false ideas and generalisations be dispelled.

1) Leimkuhler, Ferdinand F. and Anthony E. Neville, "The Uncertain Future of the Library", op. cit., p. 13.

2) Saunders, W.L., "Economic Success - The Contribution of the Information Scientist", op. cit., pp. 118-19.

In a famous study, Urquhart(1) analysed the 53,000 loan applications recorded in 1956 at the National Lending Library for Science and Technology (NLL) in London, which then had a collection of 9,120 periodicals. He showed that more than half were never consulted throughout 1956 and that 25 per cent were consulted only once. At the other end of the scale, half of the demand was satisfied by 40 journals, and 900 publications were sufficient to meet 80 per cent of requests. Although these results may seem surprising at first glance, they nevertheless agree with Pareto's law on unequal distribution of income.

However, Urquhart's study led to certain unjustifiable conclusions. The belief arose that a scientific library or an analysis centre could, without leaving users unsatisfied, dispense with exhaustive collections in favour of a limited selection of books and periodicals. Some authors, often with the best intentions, have gone so far as to conclude that a large part of scientific literature was of no value anyway and that thousands of publications could be abandoned on the grounds that "no one consults them"(2).

It is not easy to counter apparently irrefutable ideas with more scientific arguments, based for example on statistical laws of distribution and, more generally, on the law of large numbers. In any case this report is not the place for a theoretical argument; what we shall do, therefore, is to give two concrete illustrations, the first relating to subsequent experiences of the NLL.

In spite of the results of the Urquhart survey the NLL did not revise its acquisition policy and the number of periodicals went up from 9,000 to 27,000 between 1956 and 1967. In 1967, the NLL lent out more than half a million journal issues in response to requests, or as many as in all the 18 years from 1929 to 1947 combined. It should be noted that in 1930 the number of applications was only 10,000(3).

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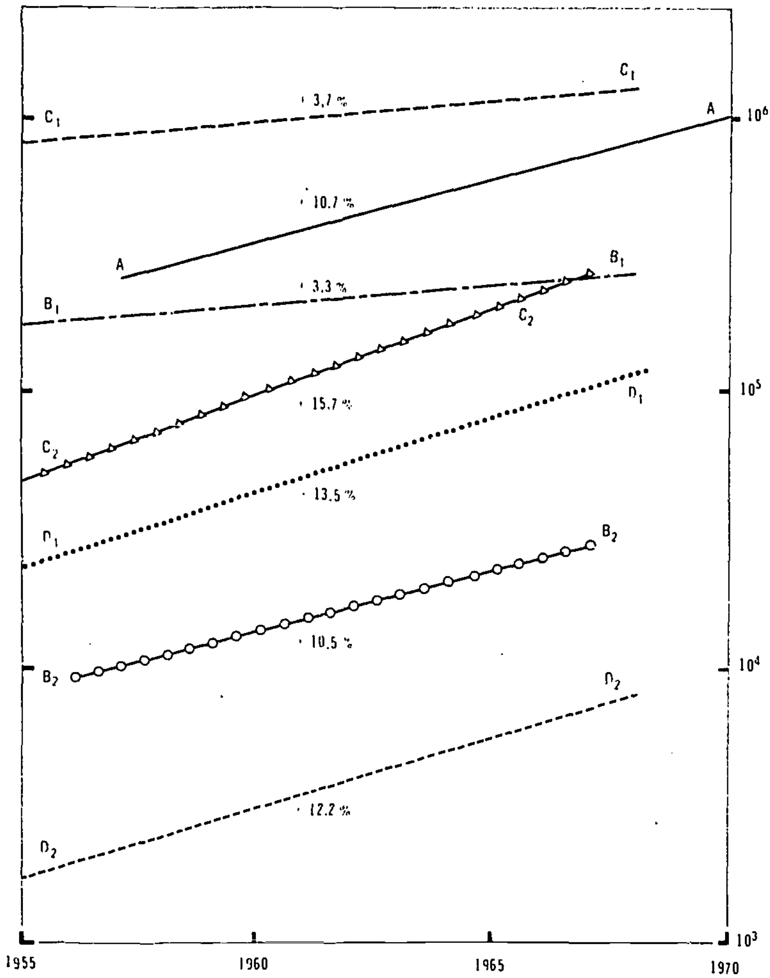
1) Urquhart, D.S., "Use of Scientific Periodicals", International Conference on Scientific Information, National Academy of Sciences, Washington, D.C., 1958, pp. 277-90.

2) No references are given here in order to avoid uselessly offending well-intentioned authors or organisations who may have expressed opinions along these lines.

3) U.K., Department of Education and Science, Education and Training for Scientific and Technological Library and Information Work, London, 1968, p. 1.

Diagram 2

RECENT TRENDS IN A NUMBER OF SELECTED INDICATORS FOR THE SUPPLY OF AND DEMAND FOR SCIENTIFIC AND TECHNICAL WORKS AND DOCUMENTS. 1955-1970



A : Number of scientific and technical abstracts listed throughout the world (cf. Table No. 1): Annual rate of increase : 10.7 per cent.

B_1 : Number of scientific works held by academic and scientific libraries in Sweden. Annual rate of increase : 3.3 per cent.

C_1 : Number of loan application recorded by academic and scientific libraries in Sweden. Annual rate of increase : 3.7 per cent.

B_2 : Number of scientific and technical journals at the National Lending Library for Science and Technology in London. Annual rate of increase : 10.5 per cent.

C_2 : Number of issues of scientific and technical journals loaned out by NLL. Annual rate of increase : 15.7 per cent.

D_1 : Number of university students in Sweden. Annual rate of increase : 13.5 per cent.

D_2 : Number of research scientists in Swedish government service. Annual rate of increase : 12.2 per cent.

It is important to understand the real meaning of these figures. Between 1930 and 1967 the use made of the collections increased exponentially at a rate of more than 9 per cent. But between 1956 and 1967, when the number of available journals was increasing by 10.5 per cent per annum, the loan requests rose by more than 15 per cent a year. In other words, the increase in supply unquestionably induced an even greater increase in demand.

A completely different situation developed at the same time in Sweden. Here the number of university students was five times greater in 1968 than 1955, an annual growth rate of 13.5 per cent - while the number of research scientists in government service quadrupled, a growth rate of 12.2 per cent per annum. Students and research scientists being the main users of academic and scientific libraries, what did the latter do to cope with this exponential and very rapid growth in potential demand?

Over the period concerned they did indeed increase their collections of scientific books, but at a considerably slower rate, i.e. 3.3 per cent per annum, no doubt for financial reasons. The related loan request curve has a similar slope, with an annual growth rate of 3.7 per cent(1).

Unlike the events at the National Lending Library in London, the failure in Sweden to increase supply sufficiently held back growth in effective demand. In both cases, the cause and effect relationship appears indisputable and the correlation between supply and utilisation is highly significant(2).

1.7 GENERAL CONCLUSIONS

This first chapter has been purely introductory and devoted wholly to a quantitative retrospect. It is intentionally brief and has taken only essential facts and marked trends into consideration.

As the reader will have realised, the accent has been on the most recent period, or more exactly the last 15 years. This is because the horizon for the forecasts set out in Chapters 2 to 4 is also fixed at 15 years, i.e. from now to about 1987.

1) The Swedish Agency for Administrative Development kindly gave the author access to detailed statistics concerning the activities of university and scientific libraries in Sweden from 1955 to 1969.

2) Refer to Diagram 2.

From this brief introductory review it is already possible to draw a certain number of conclusions, many of which are original and some unexpected. The purpose of this summary is to stress certain trends and phenomena which until now have not been fully realised or analysed but whose understanding will help us in the difficult task of forecasting.

i) The above retrospect confirms a long-held theory that the little science of earlier days has now become the world of big science in which we live, following a lengthy process of exponential growth in scientific and technical knowledge. But this is about the only point on which our conclusions agree with current ideas.

ii) Most estimates in current circulation, adopted without critical study even in the official documents of a number of major international organisations, need to be revised upward. This is particularly true of the accumulated stock of knowledge, whether this is measured by the number of journals and other sources, or by the number of articles that have appeared to date, or again by the extent - and this was known to be seriously under-estimated - to which the scientific community in the broad sense of the term has been involved in creating and disseminating information. In some cases, most earlier evaluations needed to be multiplied by two, three or even four.

iii) Similarly, the number of authors of scientific writings - which may take a wide variety of forms - is certainly very much higher (in the proportion of 3 to 1) than the figures most frequently quoted. It would appear, in particular, that social scientists as well as engineers, technicians and practitioners, are substantially and increasingly involved in creating new information. In comparative terms, technical information is at the moment increasing at a faster rate than scientific information proper.

iv) Contrary to earlier forecasts which have appeared for some ten years now, there is as yet no detectable slow-down in quantitative growth, which is still exponential. There is no trace of either weakening or saturation during the last 10 to 15 years.

v) From the middle of the 1960s signs begin to appear - and then multiply - of an even greater escalation. This is reflected in the increasing number of scientists and technical specialists, and particularly in the output of journal articles, technical reports, papers and various notes of restricted circulation - in other words, the total output of scientific and technical information.

vi) Maintenance of a high rate of expansion and, in particular, the recent tendency for this rate to increase, is largely due to the appearance of new scientific disciplines and the splitting-up of older disciplines into a number of new and/or narrower specialisations. This process is not new but appears to have gained considerably in intensity and would itself be worth studying in depth.

vii) Voluntarily or otherwise, documentation services have certainly followed (but rarely anticipated) the exponential growth in the creation and circulation of scientific and technical information. The two rising curves have striking similarities but there is sometimes a lag in time or growth rate. There is no doubt that the drive for the expansion of documentation and redistribution activities was triggered by the growing literary output of scientists and engineers.

viii) The way in which documentation services have adapted to this information explosion could only be investigated in a small number of isolated cases. In the light of this restricted circumstantial evidence it would appear that their reaction has, to some extent, been linear. For every increase in the quantity of new information, the response, with varying degrees of delay, has been an expansion either in number (i.e. the establishment of additional services and organisations), or in activity, and doubtlessly in staff. Their only answer to diversification in the scientific disciplines has been further specialisation in their respective fields.

ix) But with some rare exceptions documentation services have never exhibited a capacity for mastering the problem of the rational and co-ordinated organisation of information in its entirety and on an industrial scale.

x) On the contrary, partly (but only partly) because of financial constraints, they have operated a restrictive policy and have only cautiously increased their activities or their collections, in strong contrast to the vigour of potential demand. The inadequacy of supply has thus held back effective utilisation of available documentation and information.

xi) The nature of the correlation between supply, whatever the indicator, and satisfied demand (insofar as this is in fact satisfied), is nevertheless clear. When physically possible and when an expansionist policy is followed. the demand for information is likely to grow at the same high rate as the creation of new scientific and technical information, which at the moment is increasing at a rate of some 10 to 10.5 per cent per annum.

xii) Diagram 2 summarises and at the same time explains the above comments. Readers wishing to take this analysis further would no doubt find it interesting to study closely the slopes of the various exponential curves that are shown and compared, covering the crucial period of the last 15 years.

Chapter 2

FORECASTING BY EXTRAPOLATION

Will the sum knowledge and the volume of scientific and technical information continue to increase exponentially? Will present growth rates, which in fact are substantially higher than is generally acknowledged, be maintained? And if so, for how long?

It is naturally impossible to answer these questions with absolute certainty. Several methods of proven effectiveness enable us to establish with reasonable certainty a set of presumptions and to define the limits within which future developments will probably take place.

In this Chapter, we will be using several variants of extrapolation. The main virtue of this method is that it links the future to the past, while, conversely, the future can be anticipated by prolonging or, if necessary, modifying the trend of the earlier period.

If we were only to deal with medium-term projections, say over the next five years, it would probably be sufficient to calculate the future values of a few significant functions, empirically determined, for the last five, ten or twenty years. The only problem would then be selecting the reference period. Should a fairly long interval, hence a fairly low rate of increase be adopted, or should the most recent period marked by notable acceleration, and hence a relatively high growth rate, be taken as a starting point?

As projections must extend beyond the forecasting horizon of 1985 we are spared the need to make such a difficult preliminary choice. We are however faced with two other no less serious constraints.

No long-term extrapolation is possible without the use of at least elementary mathematical models which simultaneously explain the past and map out the future. We must, therefore, begin by examining from this angle the array of curves which can be fitted - in the mathematical or statistical sense - to the phenomena we wish to study by anticipation, after having analysed them retrospectively.

Nor can any long-term extrapolation be considered sound unless a careful examination has been made of the major factors and influences external to the model, yet capable of altering in the future, trends observed in the past. This second constraint will necessarily require a study of the likely evolution of the scientific community. Its size will directly or indirectly depend on how much scientific information is created and supplied, and on how much is demanded and used. This relationship, it will subsequently be discovered, is much more complex than has so far been recognised.

Beyond these immediate problems, our main concern throughout this Chapter will be to obtain an overall view, to achieve as narrow a range of figures as possible and, should any marked divergences remain between such figures, to find their largest common denominator.

2.1. CURVE FITTING

In determining the trend, the critical operation is to define the type of curve or, in other words, the mathematical function which will best fit - statistically speaking - the data observed.

To show in diagram form the quantitative development of scientific information, a large number of curves can certainly be conceived. In practice, however, the choice is limited - in the opinion of experts who have studied the question - to less than half a dozen functions, shown with their variants in Diagram 3.

The assumption that the volume of scientific information increases in arithmetic progression still has some supporters. This suggestion recurs every time a given statistical series shows signs of levelling off, usually temporarily, as at present in the amount of public funds allocated to research and development. Towards the middle of the decade 1960-70, the size of the scientific population in the United States, which had been steadily and rapidly growing, showed signs of flagging. A few analysts immediately inferred that "the growth of the numbers of scientists and engineers seems to be linear, not exponential",(1)

1) Cf. Mantell, LeRoy H., "On Laws of Special Abilities and the Production of Scientific Literature", American Documentation, No. 17, January 1966, pp. 8-16.

The foregoing analysis of various indices relating to creation and supply of scientific and technical information as well as demand and utilisation shows that the hypothesis of linear growth(1), with or without saturation (Fig. a and b), need not be considered.

The hypothesis of exponential growth offers several variants (fig. c, d and h of Diagram 3). In the first place, the rate of expansion may be constant, or, on the other hand, a slow increase may be followed by an accelerated increase(2). Most of the series of indices which we studied earlier cannot be analysed - partly for lack of more detailed statistics - except in terms of an assumed constant rate of increase. On the other hand, if we refer to Table 1, it will be seen that the number of abstracts of scientific and technical articles covering the 19 main disciplines first increased between 1957 and 1967 at the rate of 9.5 per cent, and from 1967 to 1971 at a substantially higher rate of 13.5 per cent per year.

Another possibility is that of doubly exponential growth (fig. e) of which the following three examples concern us directly. Rates of growth following a double-exponential curve have been recorded in respect of:

i) the speed of computers, for almost twenty years;
ii) the number of articles on the technology and applications of laser and maser beams, from their origin to the present day;
iii) more recently, literature in the field of biochemistry(3).

Expansion at such a dizzy rate is difficult for a cautious mind to accept. Yet there are abundant examples of forecasting which show lack of daring. In 1970 the number of jet aircraft in service was four times the estimate made twelve years earlier by United Aircraft. Total installed computer capacity in the

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1) Among the rare phenomena which appear to obey the "law" of linear growth, little can be mentioned apart from the mechanisation of labour measured as working time expressed in terms of hours per year, which apparently has been linear. Cf. Jantsch, Erich, Technological Forecasting in Perspective, op. cit. p. 157.

2) While the contrary is theoretically conceivable, we have yet to encounter any statistical series which in any way confirm this hypothesis.

3) Isensen, Raymond S., "Technological Forecasting in Perspective" in Management Science, op. cit.

Diagram 3

MAIN TREND LINES

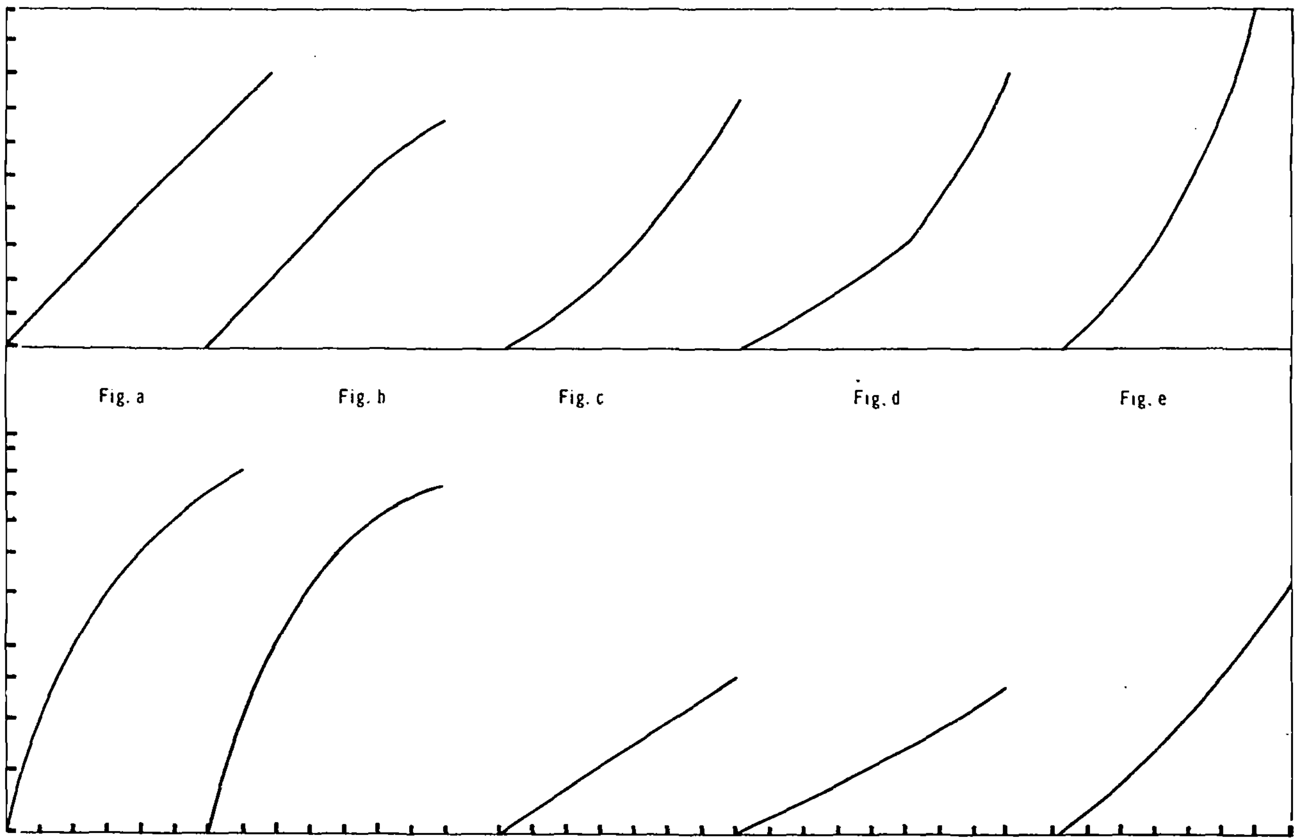


Diagram 3 *(cont'd)*

MAIN TREND LINES

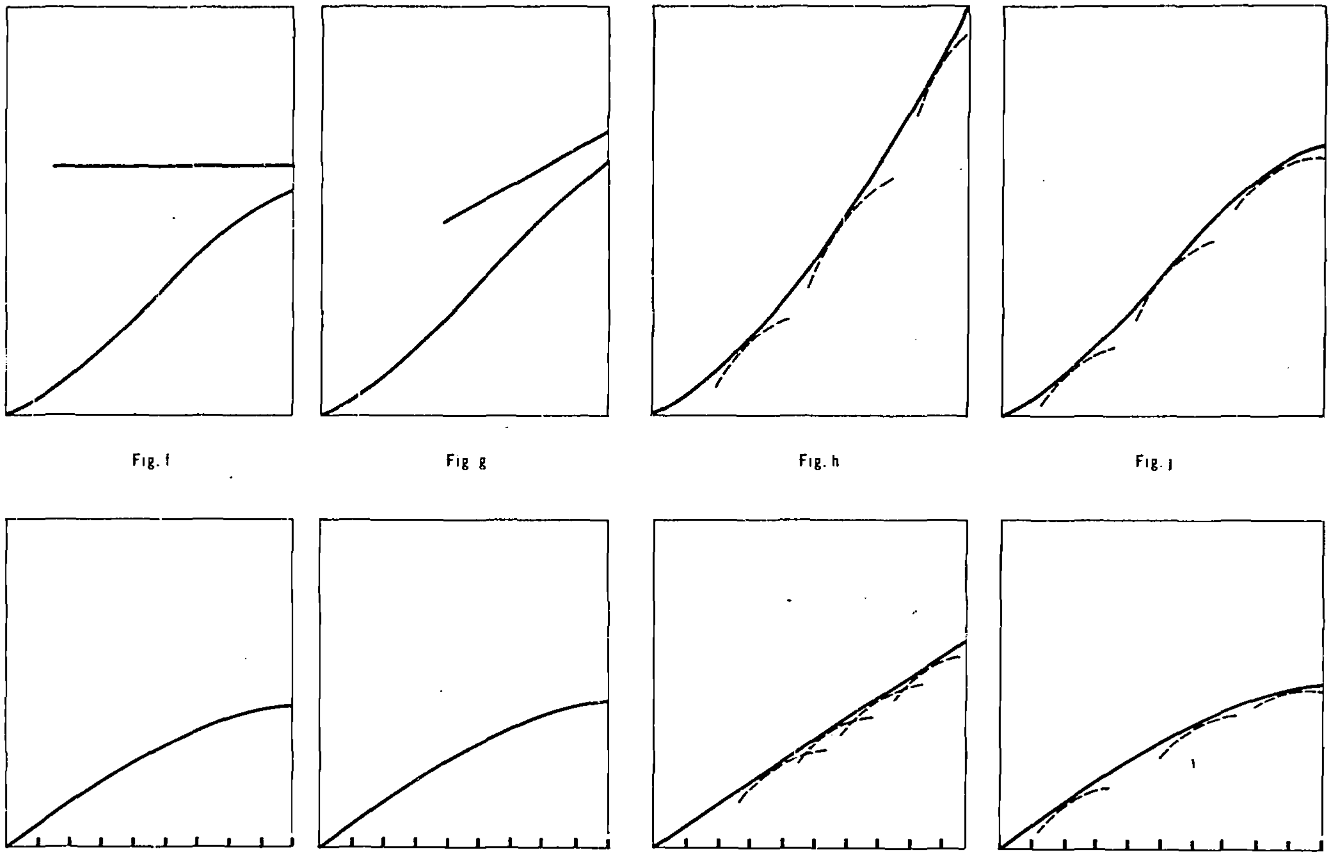


Fig. f

Fig. g

Fig. h

Fig. j

United States reached 20,000 in 1965, as compared with IBM's estimate of 4,000 units based on incorrect extrapolations(1).

The envelope curve (fig. h of Diagram 3) is an interesting variant of exponential growth, resulting from a succession of growth phenomena which individually may reach saturation point but which taken together ensure that overall expansion is sustained(2). Conceivably the sum of information relating to certain traditional scientific disciplines will ultimately no longer increase as rapidly as it did earlier, while new disciplines will replace the old, the sum total of scientific information created and disseminated thus continuing to increase as before(3).

Having rejected the hypothesis of linear growth, the choice of possible families of mathematical functions which can plot the quantitative development of scientific information is in fact reduced to one of two alternatives. Either growth of an exponential type will be assumed for the past and for some time in the future, or it will be assumed that the growth will decelerate and take the form of a logistic curve, since rapid exponential growth of any indefinite duration is inconceivable.

In both cases opinions may diverge concerning the rate - constant, accelerated or decelerated - which should be chosen. Moreover, in both cases a final conclusion can only be reached after a certain lapse of time and not on the basis merely of fluctuations which may well be temporary.

Figures f, g and i of Diagram 3, represent three variants of the logistic curve, the first being a strictly symmetrical construction of the exponential function, with the second half of the curve inverted. Its major drawback is that it is impossible to determine from empirical data alone either the maximum limit - in other words the absolute level of saturation - or the point of inflection at which the rate of increase begins to fall. The same may be said of the envelope curve, which, though more sophisticated offers the same difficulty of application.

The asymmetric logistic curve (fig. g) in the form of an elongated S with a rising upper limit (to our knowledge) has never

1) Jantsch, Erich, Technological Forecasting in Perspective, op. cit. p. 105.

2) Floyd, A. L., "A Methodology for Trend-Forecasting of Figures of Merit", in Bright, James R., Technological Forecasting for Industry and Government. Prentice-Hall Inc., Englewood Cliffs,, New Jersey, 1968, pp. 104 ss.

3) Cf. 1.3 in fine, above.

been applied in plotting the growth of scientific information.

Trend lines can of course be used either to represent the drift of a set of simple common indices, such as the number of scientific articles published at different times or variations in the number of research workers, or instead to ascertain the behaviour in time of a set of relations between several series or events which vary simultaneously, but not necessarily in a parallel or convergent manner.

A suitable procedure will be to begin (sections 2.2 and 2.3) with the simplest sort of extrapolation involving only a single variable and a limited number of parameters, before moving on, in section 2.5, to more elaborate projections.

2.2 PROJECTIONS OF THE SCIENTIFIC POPULATION

Demographic records, and particularly their breakdown by socio-economic categories, are among the weakest links in the statistical chain, even in industrialised countries. Extrapolation by relying on such dubious factors may at first sight seem risky, but we may be able to avoid this difficulty by reasoning from a set of sufficiently realistic hypotheses and by careful cross-checking.

As a point of departure we shall assume that the working population of OECD Member countries increases at the uniform rate of 1.5 per cent per year, or in other terms that it doubles in half a century.

At the same time, the increase in the scientific population has been variously estimated between 4.7 per cent and 7.2 per cent per year, respectively equivalent to a 15-year and 10-year doubling time(1). Certain categories of specialists, such as computer scientists, have increased more rapidly, i.e. by 10 per cent or more annually(2). We will therefore take these three rates as

1) According to Derek J. Solla Price, Little Science, Big Science, op. cit., p. 7, in the United States the number of university graduates doubled in 15 years and that of engineers in 10 years.

2) Bureau d'informations et de prévisions économiques- BIPE (office for Economic Information and Forecasts), Les, besoins en informaticiens. (The needs for computer scientists). Study carried out in the context of the work by the "Commission permanente de l'électronique du Plan", Paris, April 1970, pp. 52-53.

initial assumptions, and subsequently widen or narrow the scope of our investigations as necessary.

As regards the ratio of scientific population to total manpower, let us adopt the low assumption of 2 per cent, on the understanding that suitable parameters will be defined later, if necessary. In any case, this proportion is to a large extent a matter of defining the socio-economic categories to be included or not in the count of scientists, technicians and auxiliary staff.

There remains the choice of trend line and the length of the successive phases. Here again three possibilities will be adopted, i.e.

i) the scientific population will increase exponentially until horizon year 1985;

ii) a break may occur in 1980, the line taking the form of a symmetric logistic curve;

iii) a similar change may occur as early as 1975. The reference year in all three cases will be 1970.

We thus have a total of nine possible combinations, hence nine different projections. These are shown together in Table 2, which indicates the size of the scientific population estimated for 1985 as a percentage of the total working population in that same year. Thus, if the number of scientists increases by 7.2 per cent per year, the ratio of the scientific population to the working population will increase from the present figure of 2 per cent to 5.7 per cent in 1985, and so on.

According to the hypothesis chosen, this figure may vary from a minimum of 3.4 per cent to a maximum of 8.4 per cent. At first sight the low assumption yields a very low, even too low, projection, while the value extrapolated from the high assumption is clearly too great.

But these results are unreliable owing to the fact that we started with a percentage of the scientific population fixed arbitrarily at 2 per cent for the reference year 1970. To overcome this drawback, at least to some extent, we can convert the percentage projections in Table 2 into marginal projections, the surplus scientific population expected at the end of the period 1970-85 being expressed in terms of surplus manpower.

Table 2

PROJECTIONS OF THE SCIENTIFIC POPULATION FOR 1985
AS PERCENTAGE OF THE TOTAL WORKING
POPULATION FOR THE SAME YEAR

(Level 1970 = 2 per cent)

Percentages

Type of curve	Low assumption (1+r)=1.047	Medium assumption (1+r)=1.072	High assumption (1+r)=1.100
Uninterrupted exponential growth 1970-1985	4.0	5.7	8.4
Exponential growth 1970-80. becoming logistic from 1980	3.8	5.2	7.2
Exponential growth 1970-75. becoming logistic from 1975	3.4	4.2	5.2

By carrying out all these operations, figures corresponding to the different assumptions are obtained as shown in Table 3. Their interpretation is simple.

Let us take a country or group of countries with a present workforce of 100 million. The total in 1985 will be 125 million; the additional labour available will thus be 25 million. During the same period the scientific population, assuming an uninterrupted yearly exponential growth of 7.2 per cent, will have increased from 2 million to 5.67 million. In other words, it will have increased by 3.67 million persons. By dividing this last figure by the 25 million representing estimated surplus manpower in 1985, we obtain a quotient of 0.147. This ratio, which may be interpreted as a percentage (here 14.7 per cent), in fact measures the capacity of the scientific and technical sector to absorb the additional manpower available.

A ratio equal to the unit (1.0) would mean that the anticipated expansion in scientific and technical activity would alone be sufficient to absorb the entire surplus work force by 1985. In fact, Table 3 shows that this ratio will probably merely vary from 0.058 (or 5.8 per cent), corresponding to the lowest assumption of logistic growth, up to a maximum of 0.25 (or 25 per cent), resulting from the highest constant rate of exponential growth. In the extreme hypothesis, therefore, only one quarter of the surplus manpower available could be absorbed by a more than proportional growth in numbers of scientists and technicians.

Table 3

PROPORTION IN WHICH ADDITIONS TO THE LABOUR FORCE COULD BE ABSORBED BY THE EXPECTED GROWTH OF THE SCIENTIFIC POPULATION, 1970-1985

Type of curve	Low assumption (1+r)=1.047	Medium assumption (1+r)=1.072	High assumption (1+r)=1.100
Uninterrupted exponential growth 1970-1985	0.080	0.147	0.254
Exponential growth 1970-80, becoming logistic from 1980	0.073	0.127	0.207
Exponential growth 1970-75, becoming logistic from 1975	0.058	0.090	0.128

As is customary in such a case, the two extreme values can be rejected as wholly or largely improbable, thus substantially narrowing the range of projections. Table 2 shows that, all other things being equal, in 1985 the number of scientists, engineers and other technicians could account for some 3.8 per cent to 7.2 per cent of the total labour force. By rejecting the two values at both extremes, the range is reduced still further, i.e. to between 4 per cent and 5.7 per cent.

Assuming therefore that only the central values are taken into consideration, the expected increase in numbers of scientists and technicians over the next 15 years would absorb only a very modest fraction of the surplus manpower available, i.e. between 8 and 15 per cent.

These figures - which we for our part consider to be minimal - could of course be substantially or even fundamentally altered by a radical change of scientific and/or industrial policy or social policy in the developed countries. Several careful estimates in fact suggest that, owing to the automation of production processes, the industrial labour force may decrease between now and 1985 by almost one half. The ranks of the potentially unemployed would be still further swollen by natural growth of the working population.

If this is the case, which is by no means unlikely, a greatly expanded scientific and technical activity, and its corresponding increase in personnel, might be regarded as very helpful for re-channelling broad sections of a population which in the meantime had also increased. As a result of vigorous government action, the number of scientists and technicians could suddenly increase in the proportion indicated by the "high" projections of Tables 2 and 3.

2.3 PROJECTIONS OF THE VOLUME OF INFORMATION PRODUCED

The statistics of abstracts of articles in leading specialised reviews over the last 14 to 15 years constitute on the whole one of the most reliable indicators of the growth of scientific and technical information. We have already used this yardstick(1) and will use it once more, since it is certainly more reliable than any other estimate. However, in order to proceed from the extrapolation of the size of the scientific population to that of the growth of scientific and technical literature, the method of reasoning and method of calculation will have to be slightly modified, although the approach will, of course, be the same as before.

1) Cf. 1.3 above.

The fourfold increase in the number of abstracts of scientific articles recorded between 1957 and 1971 is equivalent to an exponential increase at a constant rate of more than 10 per cent per year. This permits us to make a series of calculations for the next 15 years. i.e. for an identical period as that covered by the data mentioned above.

Expansion may of course continue without slackening until the horizon year. On the other hand, a slow-down could occur at any time. We may assume this to happen either around 1975 or not until around 1980, and that it will take the form of a logistic curve. We regard as quite improbable, however, any immediate levelling off, since for the last four or five years a further acceleration has been noted.

Diagram 4 shows graphically these different possibilities, but transposes them for the sake of convenience in terms of two 15-year periods, one before and one after 1970. It consists of three distinct phases. For the period 1955 to 1970 the curve is exponential, at the rate of 10 per cent, and corresponds to the trend shown by statistics. The trend line is simply extended over the next five years. From 1975 we have three curves, the highest being purely exponential; the lowest, a logistic curve, marked by a break in 1975; and the middle curve, another logistic curve, breaking only in 1980.

Over 30 years, between 1955 and 1985 approximately, the number of abstracts would have multiplied, according to the hypothesis adopted, by a factor of 11, 13.5 or 17.5.

It is by no means evident that, for extrapolations over the coming period, we should base ourselves on the 10 per cent rate recorded over the previous period. We may assume that this parameter will vary between a yearly minimum of 7.2 per cent and a maximum of 13.5 per cent. The first of these figures is equivalent to doubling every ten years, i.e. a rate below the lowest growth rates recorded in the least "explosive" disciplines. The maximum rate envisaged - at least for the moment - of 13.5 per cent simply corresponds to the actual increase in abstracts published between 1967 and 1971.

On the basis of these values it is easy to calculate a series of forecasts by extrapolation. The results so obtained can also be expressed in relative terms by taking 1970 = 100 as the base and they can be graphically represented (Diagram 5) by three similar groups of functions.

Diagram 4

VOLUME OF SCIENTIFIC AND TECHNICAL INFORMATION 1955-70 TREND AND 1970-85 PROJECTIONS FITTING AN EXPONENTIAL AND TWO LOGISTIC CURVES AT RATE 1955-75 OF (1 + r) = 1.10

(Base 1955 = 100)

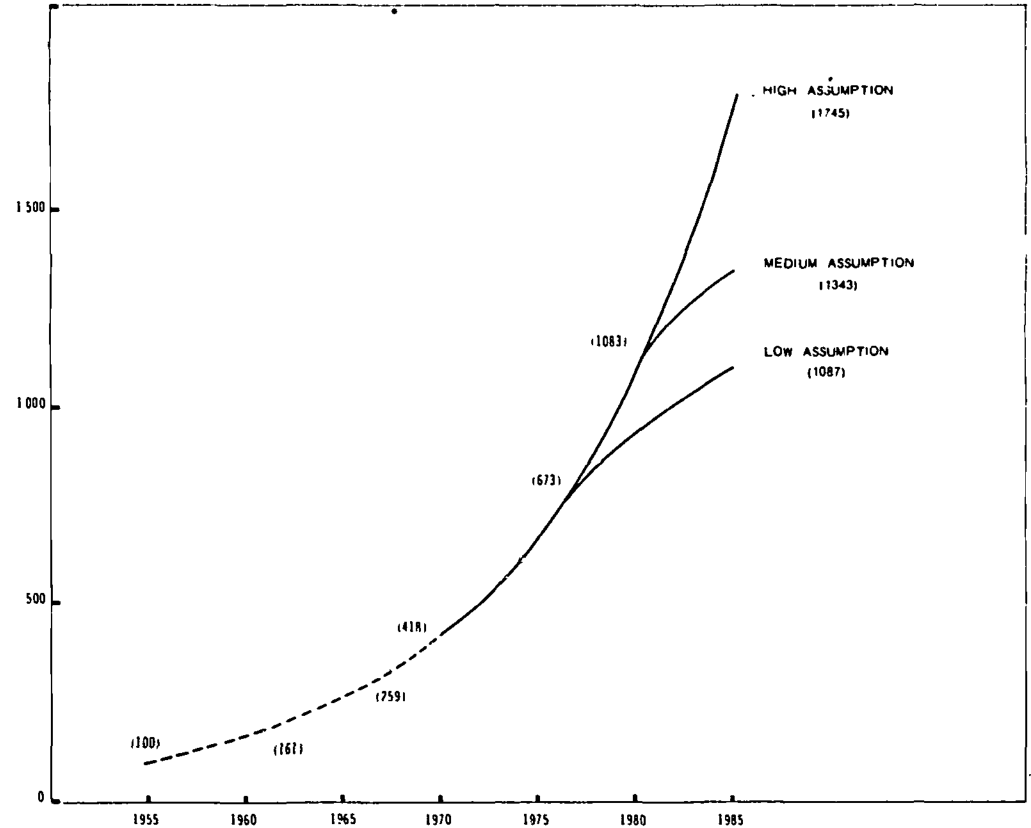
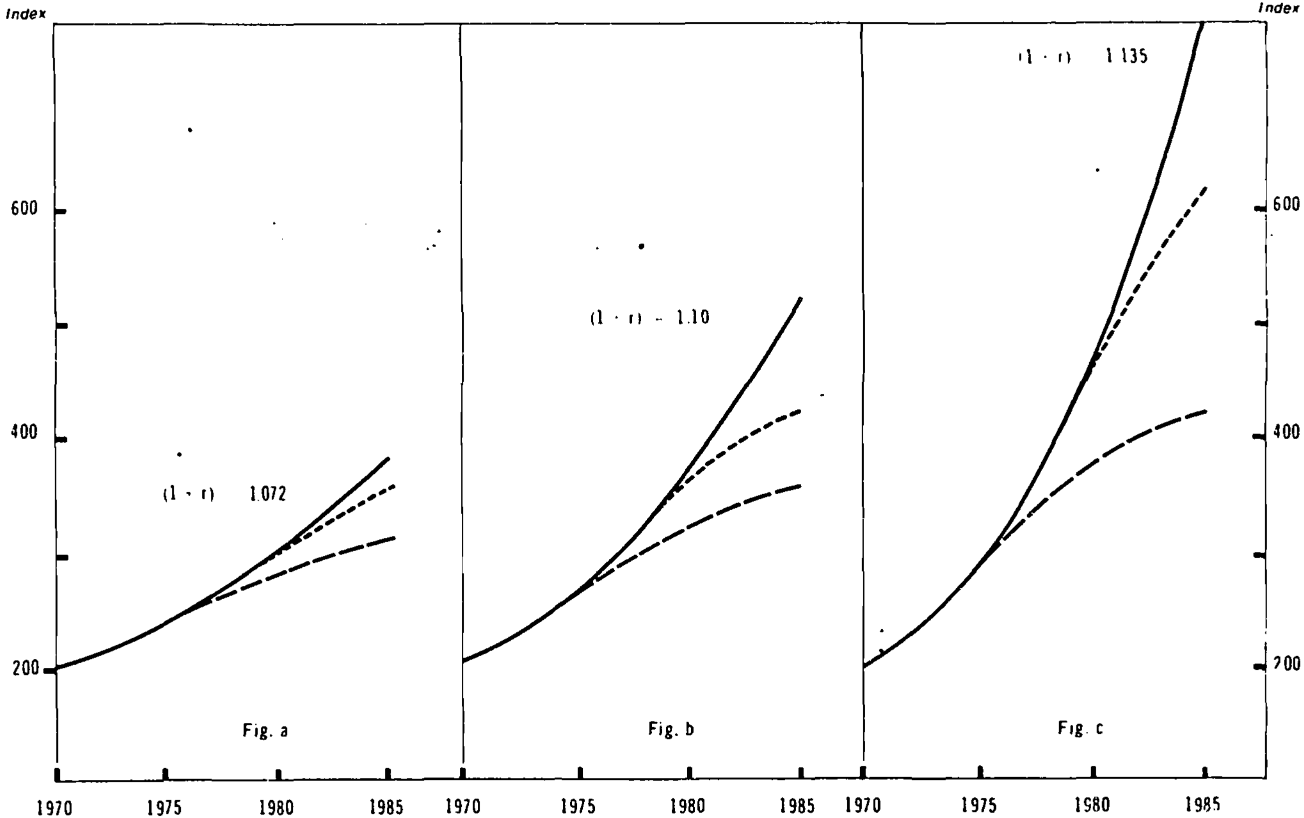


Diagram 5

EXPECTED INCREASE IN SCIENTIFIC AND TECHNICAL INFORMATION, 1970-85
FITTING AN EXPONENTIAL AND TWO LOGISTIC CURVES



Together. these three groups of curves yield a wide series of projections ranging from an index of 218 to one of 668 for the year 1985, i.e. a spread of 1 to 3. By symmetrically rejecting the two extreme values the spread would be appreciably narrowed, to between 252 and 521, i.e. the variation would now be no more than from one to two(1).

We can however reduce this spread a little further. The three groups of curves are shown together on Diagram 6. We can see at a glance that they overlap in several places. Moreover. the low logistic curve corresponding to the highest initial rate (13.5 per cent) is very close to the pure exponential curve corresponding to the lowest rate (7.2 per cent), i.e. indices 324 and 283 respectively.

What, in fact, do these indices mean? They may simply be taken as factors by which to multiply the present number of abstracts in order to obtain the corresponding 1985 numbers by extrapolation. Thus the highest index of all (668) is approximately equivalent to multiplication by a factor of 6.7. The results of this operation are indicated in Table 4, where they are shown in descending order, the first column indicating the projections based on the initial rate of 13.5 per cent; the second of 10 per cent; and the third of 7.2 per cent.

Table 4

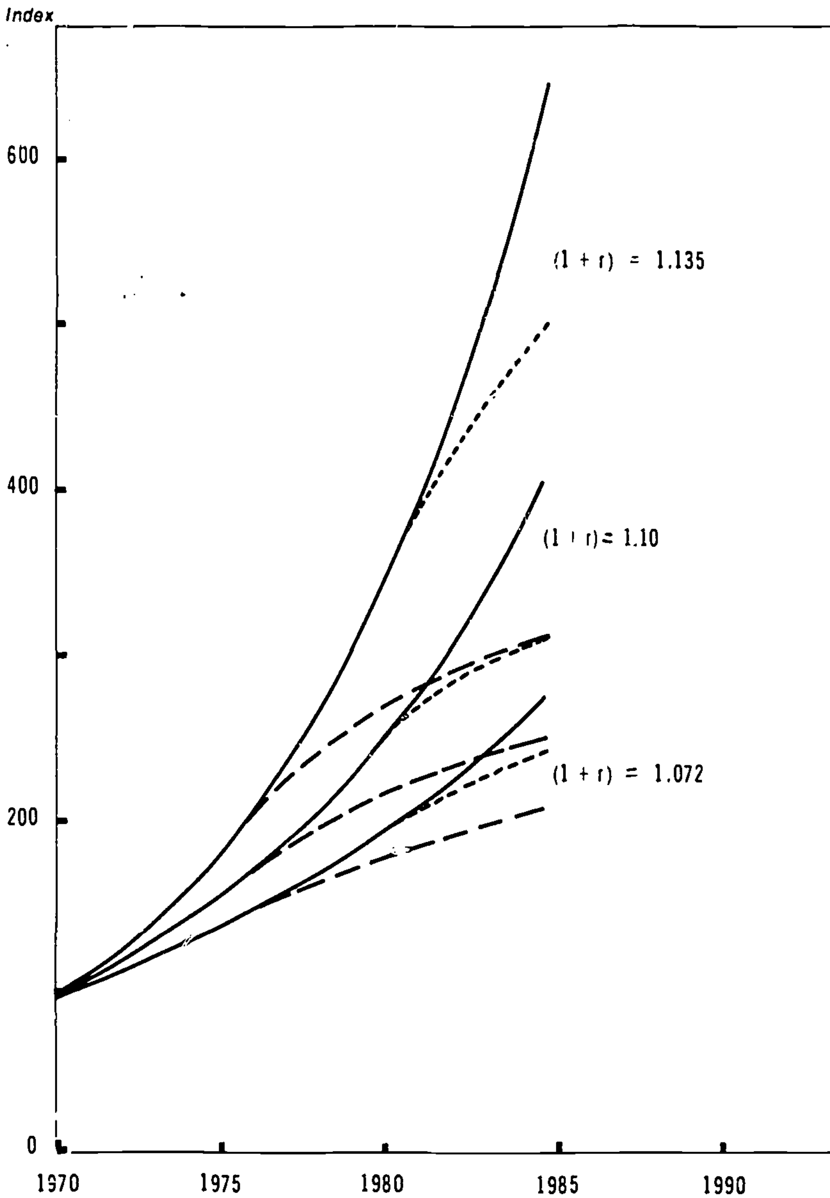
MULTIPLICATION CO-EFFICIENTS CORRESPONDING TO PROJECTIONS BY EXTRAPOLATION, OBTAINED ON THE BASIS OF ASSUMPTIONS IN DIAGRAM 3

(1 + r) = 1.135	(1 + r) = 1.10	(1 + r) = 1.072
6.7	. .	. .
5.2	4.2	. .
3.2	3.2	2.8
. .	2.6	2.6
. .	. .	2.2

1) A dispersion of this kind - from one to two - is not unusual for forecasts covering a period as long as 15 years.

Diagram 6

EXPECTED INCREASE
IN SCIENTIFIC AND TECHNICAL INFORMATION:
1985 PROJECTIONS
(Base 1970 = 100)



The arrangements of the figures in this table is very significant. Assuming an exponential growth of 10 per cent per year between 1970 and 1980, followed by a logistic decrease between 1980 and 1985, the same result is reached as by assuming an exponential growth rate of 7.2 per cent for 1970-75, followed by a logistic deceleration for 1975-85. Moreover, the results are identical (factor: 3.2) in the case of the low assumption corresponding to an initial rate of 13.5 per cent, and of the medium assumption corresponding to a rate of 10 per cent.

There is every indication that projections to within a year or two of the 1985 horizon might well lie within the index range of some 300 to 400. In other words, the number of scientific and technical abstracts would then be three or four times their present number. This estimate is naturally subject to the usual reservation, i.e. all other things being equal.

We will revert later - in section 2.5 - to this condition and its implications.

2.4 INTERVAL OF ESTIMATION AND MARGINS OF ERROR

The method of extrapolation used so far, which consists in fitting several trend lines to a chronological series of simple indices, offers many possibilities of analysis. It can, for example, provide indications regarding the margin of error inherent in projections of the scientific work force (2.2) and number of abstracts (2.3) for the next 15 years.

To revert to Diagram 5, for example, for the final year of 1985, it shows a range of nine projected values based on the number of abstracts published during the previous 15 years. But instead of comparing these 1985 values among themselves, i.e. by reading them vertically on the diagram, let us instead compare them horizontally in order to determine the differences in terms of years.

The three curves in fig. a clearly show that the minimum projection for 1985, i.e. the index 218 which would result from an exponential growth rate of 7.2 per cent, followed by a logistic decrease from 1975, would be reached as early as 1981, assuming that exponential growth steadily continues. There is thus a difference of four years. For values extrapolated from the high assumption and medium assumption respectively the difference is only 22 months.

Fig. b and fig. c of the same diagram show at a glance that the differences between the 1985 projections, corresponding to the different trend lines, and initial rates of 10 per cent or 13.5 per cent are about three years and five years in the first case; under three and seven years in the second case.

The margins of error, which are small for the low rates, thus appear to increase as the rates increase(1). The maximum difference of seven years is so great that the assumption of an uninterrupted exponential growth rate of 13.5 per cent throughout the 15-year period must be rejected as improbable. If this extreme case is eliminated from the field of investigation, all other margins of error will be contained in a short interval of some 22 to 60 months.

In sum, the assumption of a decelerating growth rate following a logistic curve is subject to a downward error, compared with purely exponential growth, of some two to five years. In other words, the low assumptions theoretically referring to the horizon year 1985 might well be reached by 1981 or 1983(2).

At this point of reasoning, another important question arises, which in fact is one of principle. All the previous extrapolations were based on the assumption that only two types of trend lines existed, represented respectively by the exponential function F_1 (t), and the logistic function $F_2(t)$, the latter being applicable either from 1980 or as soon as 1975(3).

It is by no means clear that deceleration - if any deceleration is to occur within 15 years - must necessarily take the form of a logistic curve, since other types of growth are conceivable.

1) The relationship is approximately linear, i.e. average differences of about 3 years, 4 years and slightly over 5 years for the rates of 7.2, 10 and 13.5 per cent.

2) The converse is not true, however, since beyond 1985 the differences expressed in terms of volume or years become greater very rapidly, especially for initially high rates. A projection over a longer period, say 20 years, would therefore be wholly speculative. On the other hand, if we were to confine ourselves to the coming ten years, from 1970 to 1980, or even from 1972 to 1982, it would make little difference whether an exponential or logistic curve were fitted, since in this case the respective values extrapolated would be subject to a margin of error of one to three years at most.

3) To simplify matters, $F_2(t)$ will designate the logistic curve beginning in 1975, hence corresponding to the low assumption, while exponential curve $F_1(t)$ will refer to the high assumption. In all cases t = time in terms of years. The equation of the exponential curve can thus be written:

$$F_1(t) = k.e^{ht}$$

(Footnote 3 continued on next page).

We shall confine ourselves to examining the three or four most likely possibilities.

From some point of inflection, which we will put at 1975, growth might take the form of a potential function. In this event, two possibilities must be considered; either an accelerated growth rate $F_3(t)$, although this will be slower than exponential growth(1), or a decelerated growth rate $F_4(t)$(2). Diagram 7 shows clearly that $F_3(t)$ and $F_4(t)$ are located between the extreme functions $F_1(t)$ and $F_2(t)$.

Moreover, it may well be that growth of the amount of scientific information, as measured by the number of abstracted articles, is of the logarithmic type, i.e. even slower than in the previous assumptions. The trend line $F_5(t)$ plotted in this case would hence be located below the other lines but above the pure logistic curve(3).

Finally a low, damped growth rate cannot be excluded. This would take the form of a Gompertz curve $F_6(t)$, along an oblique asymptote slightly inclined towards the horizontal(4).

(Footnote 3 continued from previous page).

where k and h are two parameters estimated from observed data and e = 2.71828 (natural logbase); or

$$F_1(t) = k.e^{ht} + z$$

where z is a constant.

$F_2(t)$ can be deduced from the presumed symmetry of the logistic curve, which is simply inverted from a point of inflection r. In the present case r = 5, since the break is expected to occur by 1975.

1) $F_3(t) = F_1(t)$ when $t \leq r$, but

$$F_3(t) = \frac{F_1^1(t).tx}{r^x}$$ when $t \geq r$ and provided $x > 1$

2) The equation for $F_4(t)$ is identical, but here x must be located between 0 and 1, i.e. : $0 < x < 1$

3) $F_5(t) = F_1(t)$ when $t \leq r$, whereas $F_5^2(t) = F_1^1(t)$. log t when $t \geq r$.

4) Instead of a horizontal asymptote, which characterises a pure logistic curve. The equation for the Gompertz curve may most simply be written:

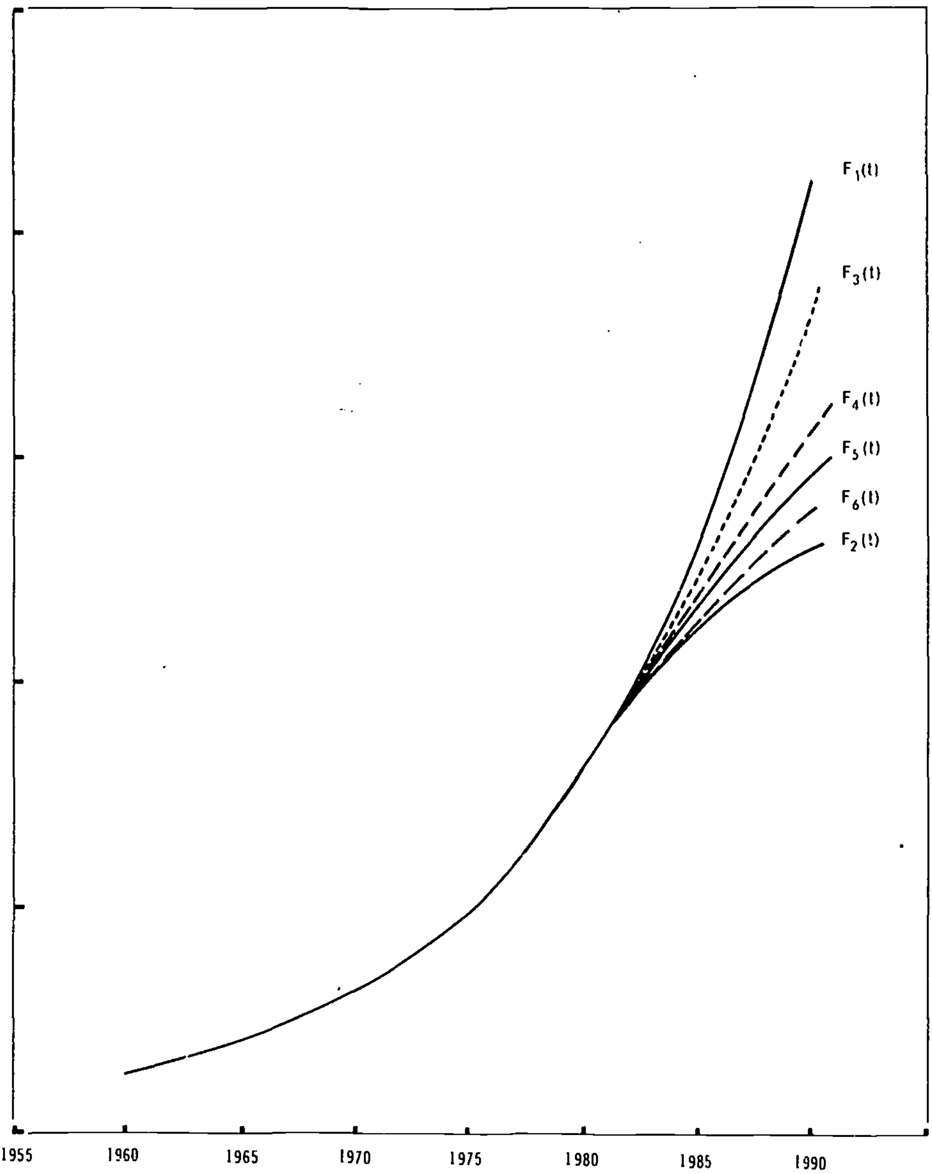
$$F_6(t) = k.m^{t^h}$$, or in logarithmic form:

$$\log F_6(t) = \log k + (\log m).\ t^h$$

where k, m and h are three parameters estimated from observed data. As previously, the path of the Gompertz curve thus defined would only be valid for $t \geq r$.

Diagram 7

TREND LINES SHOWING THE ASSUMED QUANTITATIVE GROWTH OF SCIENTIFIC ANO TECHNICAL INFORMATION. 1955 - 1985



Should the presumed inflection not occur until after 1975, say in 1980, the entire set of hypothetical trend lines would commensurately be shifted towards the right. In this event the range of values expected in 1985 would be appreciably narrowed.

Better than any mathematical formula, Diagram 7 highlights the central point of the argument, which is the choice of a curve best fitting the observed data, in this instance the statistics for published scientific abstracts. The findings may be summarised as follows:

i) _A priori_, the choice is not merely between two types of growth. The exponential curve and the logistic curve, where inflection occurs early, are actually the two extreme assumptions.

ii) Between these limits there is a whole range of curves which can be fitted, as required, to the observed data. In theory it is the best statistical fit obtained which should designate the most appropriate trend line and thereby determine the value of the relevant projections.

iii) Unfortunately the statistics now available are inadequate for making a rational choice. We must therefore revert to the initial assumptions, supplemented and substantiated by the reasoning set out above.

iv) For all these reasons the initial projections in sections 2.2 and 2.3 should no doubt be revised upwards. In other words the average forecasts we have reached should not only be regarded as reasonable but on the conservative side. _A fortiori_ this is one of the projections for the scientific population, where the growth rates are relatively low.

2.5 VARIATIONS IN THE PRODUCTIVITY OF SCIENTISTS

The quantitative growth of scientific information is so complex a phenomenon that we cannot merely study the behaviour of a series of simple indices one after the other and in isolation and deduce a set of forecasts for the future. Our previous extrapolations must be supplemented by at least a cursory examination of relations between the principal variables applicable.

It is a fact that the volume of literature produced by scientists and technicians, which we measured by counting the number of published abstracts, has increased, and is still increasing, at a faster rate than the number of scientists and technicians. There is every indication that both these upward trends have followed an exponential pattern but at appreciably different rates.

Through the years, provided this difference in rate continues, important effects arise which must be analysed. Let us suppose that the number of published scientific articles increases by 10 per cent each year while the number of active scientists and technicians steadily rises by 7.2 per cent. Under these conditions the "productivity" of the scientific community as a whole will gradually increase from 100, the index for the base year, to 114.2 at the end of five years, 129.5 at the end of 10 years and 147.7 in 15 years. In 15 years it will therefore rise by nearly one half, equivalent to an exponential growth at a constant yearly rate of 2.6 per cent.

Since this is what has actually happened, it would be wrong to assume that the literary "productivity" of scientists and/or technicians is constant(1). It is also necessary to reject any growth model for scientific information which is based on an assumed proportionality between the scientific population and the volume of scientific information regardless of the measurement indices selected(2).

What is the relationship between the number of working scientists and the number of original papers written by them? By analogy, although without supporting evidence, the relation-

1) It is rather surprising to discover such an error in de Solla Price, Derek J., Little Science, Big Science, op. cit., which mentions an average of 3.5 papers per man (p. 49). But it is even more surprising to find it in Jantsch, Erich: Technological Forecasting in Perspective, op. cit., p. 146. Jantsch writes: "Numerical values, according to de Solla Price (and assuming an average productive life of 35 years for a scientist) would be approximately: q = 0.1 paper per year per investigator for the broad average; q = 0.8 for the top 10 per cent; q = 2.0 for the top 2 per cent". Ibid.

2) Thus the model proposed by Isenson assumes an exponential growth for numbers of investigators and constant average productivity, this productivity being measured by the amount of information produced per investigator per year. Whence Isenson concludes that the growth of information is proportional to population growth and that the cumulative stock of information also grows exponentially - until it later runs up against an absolute limit, which brings Isenson back to a pure logistic curve. See Isenson, Raymond, "Technological Forecasting in Perspective", in Management Science, op. cit.

ship may be assumed to be not very remote from the geometric progression which characterises the "productivity" of scientific authors when measured in terms of abstracts. Similarly, without offending logic or common sense, the scientific and engineering community may be expected to produce, at an ever faster rate, scientific documents other than magazine articles. such as technical reports or papers appearing in conference proceedings. Although again no accurate statistical evidence is available, such forms of communication are known to be increasing.

On the other hand, we have no way of similarly evaluating the overall productivity of scientists, since. owing again to the lack of data. there is no general yardstick for measuring all forms of writing and communication. Some idea may however be gained by indirect evaluation based on the cost of R & D activities.

The figures for R & D expenditure are of a highly disparate nature. Their significance is lessened further by inflation and successive devaluations or revaluations and by the fact that the statistics though recent, relate to different periods of varying length, depending on the country.

Despite all these reservations the available figures enable a graph to be plotted (Diagram 8). While it does not make any claim to mathematical precision it succeeds in highlighting a number of dominant trends. In the United States R & D expenditure grew exponentially by 15.8 per cent from 1950 to 1960, but only by 7.2 per cent from 1960 to 1972. Over the entire period from 1950 to 1972 the average rate nevertheless reached 13.8 per cent. Much the same rate, i.e. 13.6 per cent, in recent years has marked the growth of appropriations allocated to R & D by the six Common Market countries. In Japan, in the ten years from 1959 to 1969, growth was constant, the yearly rate being 20 per cent.

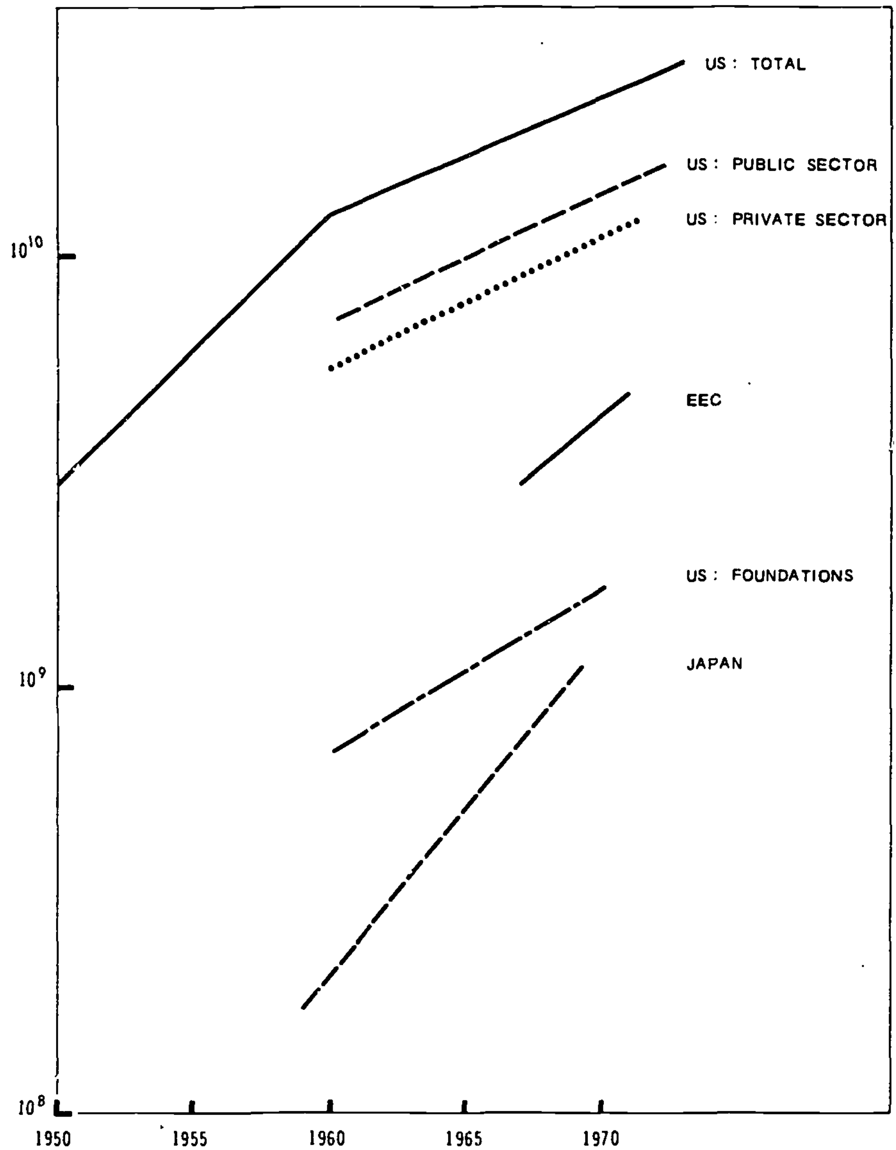
Altogether. R & D expenditure in the developed countries as a whole, over the last 15 years grew exponentially at a gross rate somewhere between 13 and 16 per cent, and the net rate at constant prices was between 10 and 12 per cent, or perhaps even 11 and 13 per cent.

If, as seems likely the number of scientists has increased at a rate of between 4.7 and 7.2 per cent(1), then the unit cost per scientists has also increased exponentially, at a rate of 5 or 6 per cent each year.

1) Which means doubling in 10 years or 15 years.

Diagram 8

GROWTH OF R & D EXPENDITURE, 1950 – 72



It will be noted that in any case the unit cost per scientist exceeds annual productivity growth, i.e. 2.6 per cent, at least so far as productivity is evaluated in terms of abstracts alone, as we have done. But is it legitimate to make any such comparison?

From the standpoint of theory, including economic theory, this is undoubtedly the case. Is marginal productivity not always measured in terms of marginal costs?(1). Does not an entrepreneur normally increase his marginal input bearing in mind the expected increases in output?

When it comes to R & D expenditure, no doubt the entrepreneur behaves less "rationally", since he can assess only globally, and much later, the additional profits he has earned. Moreover, fundamental research is mainly conducted in the public sector, which rarely adopts such a marginal approach. On the other hand, in recent years, expenditure for industrial research in the United States seems to have increased more rapidly than the amount of public funds allocated to R & D. As this is also true for Japan and Western Europe, it may be assumed that industry finds increased R & D expenditure to be worthwhile, and that finally the marginal principle, according to which marginal expenditure = marginal productivity, is more or less true.

The second possible objection is of another kind. There is no evidence to show that the growth of research productivity represents productivity in terms of newly created information. Yet this is quite likely. The activity of the research worker and his staff must take the material form of a study monograph, report or mere technical memorandum, otherwise the employer - the institute, laboratory or company - would terminate the "unproductive" activities of its scientific and technical personnel.

The literary productivity of scientists and technicians must therefore be presumed to bear some relationship to their research productivity, so that the trends of the two variables are approximately parallel. Literary productivity can therefore be assumed to increase in relation to some given form of communication - magazine articles or technical reports - at a rate of about 2.5 per cent, and in relation to all forms of communication at a higher yearly rate, perhaps of as much as 4 or 5 per cent.

The conclusion just reached is compatible with the previous projections as well as with observations in the field.

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1) The growth rates calculated are, in fact, marginal rates.

2.6 GENERAL CONCLUSIONS

Extrapolations, especially over the long term, can by no means be regarded as a purely mechanical exercise the results of which are known as soon as the trends for the earlier period have been determined. The successive analyses undertaken in this chapter to discover the future quantitative pattern of scientific and technical information have allowed us to identify several new aspects and to make a number of fairly consistent forecasts.

i) It is the varying productive capacity of scientists and technicians which must be held primarily accountable for the speedier growth of scientific and technical information in modern times and especially in years to come. This would be a trite conclusion in regard to any other human activity, where by definition progress depends on the higher productivity of labour. But in our particular field the concept is a new one and diametrically opposed to anything so far spoken or written on the subject.

ii) The rapid increase in our knowledge - hence in the amount of our information - essentially results from the joint and simultaneous action of two factors: the steadily mounting number of research workers and auxiliary staff, and the equally steady improvement of their average productivity. Assuming the scientific community to increase by some 7 per cent each year and the amount of scientific and technical information created to increase by 11 per cent, the average productivity of scientific authors must therefore rise by some 4 per cent.

iii) These two factors therefore contribute to the final result at a ratio of, at present, 2 to 1. Inevitably there will come a time when the ratio is reversed. Over the very long term the scientific population will cease to grow faster than the total population, and when this threshold is reached the only potential source of speedier progress will be greater inventive and literary productivity.

iv) But we have not yet reached this stage, far from it. In fact, our previous analysis shows that during the next 15 years - perhaps longer - the number of scientists and technicians could still grow exponentially by as much as 7 per cent each year without causing the least inconvenience to other socio-economic categories and other sectors of activity.

v) Between now and 1985 the mechanisation and automation of industry will free a considerable proportion - perhaps as much as one half - of manpower. A greatly expanded scientific work force will then no doubt prove helpful in solving the thorny problem of employment.

vi) That some 6 to 7 per cent of the work force should some day be employed in the science sector seems unthinkable now but will certainly seem less revolutionary at the beginning of the next decade. Compared with present levels, the number of scientists and technicians may increase threefold between now and 1985. At all events a twofold gain must be regarded as a minimum estimate.

vii) Generally speaking, certain "limits", which only a short while ago were believed to be very nearly if not actually reached and in any case impossible to exceed, are shown in the light of our extrapolations to be far less absolute, more flexible and more remote. Neither science nor scientific information in the immediate or the near future will reach saturation point.

viii) There is nothing to show that in the foreseeable future the logistic "law" with which we have so often been threatened will curb research and discovery or limit the creation and dissemination of scientific and technical information. True, the criteria available for assessment do not forever preclude such an eventuality but they do not show it to be inescapable either. On the contrary, the future of scientific and technical information seems wide open to question, with projections and hence possibilities easily ranging from a fourfold to sixfold increase in volume during the next 15 years.

ix) The figure of 8 million scientific documents yearly put into circulation in 1985, as against two million in 1970 must therefore be considered a conservative forecast. A mere continuation of the present tendency (1967-71) would produce a total of some 13 to 14 million per year, i.e. equivalent to the stock accumulated since the origins of science until the present day. A projection midway between these figures would seem fairly reasonable.

x) Would it then be rational to envisage a doubly exponential growth rate? Until now this type of expansion has been confined to a few narrowly circumscribed fields and has only been observed over a relatively brief period. At a later date such a hypothesis may perhaps be substantiated to some extent by other forecasting methods, but not at present, on the basis of quantitative extrapolations alone.

xi) An important OECD report(1) recently recommended the adoption of a science policy more closely directed towards social goals, particularly the protection and improvement of the environment and the quality of life. It is as yet impossible to assess the effects such a shift in direction would be bound to have on research and on scientific and technical information. If this were to happen, would not our extrapolations of future events - even the highest values projected for 1985 - turn out to be very timid indeed compared with reality? In particular, would not the 13.5 per cent growth rate, so far regarded as impossible to sustain over a long period, underestimate the possibility of more powerful successive accelerations in the future?

In order to answer this type of question - and they are legion - we must explore the future by using methods other than mere quantitative extrapolation. This is the purpose of Chapters 3 and 4.

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1) OECD, Science, Growth and Society. Report of the Secretary-General's Ad Hoc Group on New Concepts of Science Policy, Paris, 1971.

Chapter 3

FORESEEABLE AUTOMATION IN THE TRANSFER OF KNOWLEDGE

The concept of scientific information depends very much on what we understand by knowledge and vice versa. In Chapters 1 and 2 we simply followed the most usual practice, which is to reserve the terms "scientific and technical information" for those concepts and data which are gathered, processed and also used by the scientific community and possibly their immediate supporting staff.

Against this restrictive approach it is permitted to take a wider view. Even assuming that the community of scientists, and their staffs is indeed the only source of scientific and technical information - which, incidentally, is not quite true - it clearly neither is nor should be the sole recipient of this accumulation of information, constantly renewed by fresh discoveries and knowledge. Other social and professional categories must not only have access to it but also have their say with regard to its content, form, and production and transfer procedures.

This wider circle of users may be defined in different ways. Since this is by no means a question of esoteric concepts, but of everyday reality, any definition (3.1) will do, so long as it allows the main categories of people concerned to be listed and classified consistently and their respective needs to be similarly defined.

This wider field of investigations compels us to deal with orders of magnitude quite incommensurate with scientific information which is confined to the scientific and technical sectors alone. The resulting quantified forecasts will reflect this change of scale.

Lastly, we shall be unable to use the same working methods as before. Forecasts by extrapolation, useful though they may be when studying a well-defined sector or a simple, precisely identified phenomenon, can hardly be applied to complex phenomenological structures. In Chapter 3 we will mainly employ scenario writing, and we shall draw much of our material from a number of Delphi-type surveys carried out in the United States, Europe, and especially Japan.

3.1 THE KNOWLEDGE AND INFORMATION INDUSTRY

Professor Fritz Machlup, of Chicago University, was among the first, if not the very first, to use the concept of the "knowledge industry" and draw attention to both its material importance and its growth(1). According to Machlup this industry comprises all the activities relating to the production, distribution and consumption of knowledge in all its forms.

This industry would thus include:

i) activities connected with fundamental and applied scientific research and with development;

ii) education and training including, no doubt, continued and refresher training; and

iii) the vast realm of mass media, i.e. publishing, the press, radio, television and so forth. As early as 1958 the knowledge industry thus defined accounted in the United States for nearly $136 billion, employed 24 million people and absorbed 29 per cent of the gross national product.

The most striking feature of this industry at that time was its high growth rate of some 10 per cent per year, compared with only 5 per cent for GNP.

Five years later, in 1963, another author(2) more than confirmed Machlup's estimates by calculating that in 1963 the knowledge produced a value added of some $159 billion or 33 per cent of GNP in the United States. Another five years later Professor Marshak(3) made other evaluations and several medium-term projections, which showed that in 1968 the knowledge industry was approaching 40 per cent of the United States GNP.

1) John McHale, Final Copy-Information Technology, New York, 1971, p. 1.

2) Gilbert Burck, "Knowledge, the Biggest Growth Industry of Them All". Fortune, November 1964.

3) J. Marschak, "Economics of Inquiring, Communicating, Deciding", American Economic Review, Vol. 58, No. 2, 1968, pp. 1-8.

At this point three questions arise:

i) Can and will expansion continue at its present rate?
ii) Is Machlup's definition of the knowledge industry complete, too broad or inadequate?
iii) Is the concept operational, especially for purposes of forecasting?

Thanks to our previous analyses(1), we are fairly well equipped to answer the first question. There is nothing to prevent the number of scientists and technologists from rising exponentially between now and 1985 at a yearly rate of 7 per cent, perhaps more. R & D expenditure, after all, has increased by some 13 to 16 per cent, or 10 to 13 per cent at constant prices, and although lately the rate has slowed down in the United States it has increased rapidly in Western Europe, and especially in Japan and the USSR. Moreover, the rate quoted by Machlup and Marschak (10 per cent) does not seem unduly high by comparison.

Our line of reasoning with regard to the growth rate of researchers and technicians may be applied to education, communications media and so forth, especially since, as pointed out earlier, by 1985 new jobs will have to be found for all the employees compelled to leave industry as a result of the automation of production processes.

McHale may well have been thinking of all these developments which, after all, are foreseeable, when he wrote concerning the knowledge industry: "The end is not yet in sight"(2). To be on the safe side we shall endorse this forecast only as far as 1970-85 which is the period we are concerned with here.

Secondly, the limits of this composite industry should be clearly defined. Insofar as the industry aims not only to create and disseminate knowledge but also to use it, it would be paradoxical to include only part of the medical field, in this instance medical research and medical training, and to leave out the vast field of medical care, i.e. practical medicine and health. It is this broader definition which we shall be using.

1) See section 2.2 and conclusions under 2.6, items (iv) and (v).

2) Cf. John McHale, "The Changing Information Environment: A Selective Topography" in Information Technology: Some Critical Implications for Decision Makers, 1971-1990, op. cit. p. 1.

Some experts have moreover suggested that the activities of the knowledge industry should include certain categories of services, i.e. those performed by lawyers, accountants, tax advisers, land surveyors, etc. We will not adopt this definition, at least not for the time being. The danger inherent in too broad a definition will be immediately apparent. If lawyers are included, why not judges, the courts or the police? Why not the whole of public administration?

Our middle-of-the-road choice has been dictated by considerations of efficiency. To advance in this study we need an operational, manageable concept lending itself without undue difficulty to the measurement and evaluation of the components. Furthermore it must be a realistic concept, as close as possible to concrete situations, and it must therefore deal with activities which are complementary and, above all, of a similar nature.

In short, recognising the deep affinities that exist between knowledge and information, we shall consider in this chapter that any transfer of knowledge is equivalent to a transfer of information and vice versa. We shall postulate that the rationale of the knowledge industry is to secure the transmission of knowledge/information in all directions and for the benefit of those activities which make up the industry, i.e. in the last resort for the benefit of the people working in it.

It is a vast field which will soon include nearly half the working and student population.

3.2. A SCENARIO BASED ON DELPHI SURVEYS

What will the knowledge industry be like by 1985 or thereabouts? How large will it be? What will be its dominant features? What will be the qualitative aspects of its development in fifteen years from now?

Two methods in particular, the Delphi techniques and scenario writing, could help to develop a set of forecasts. We must, however, tailor our ambitions to our resources and adapt either method to the nature of the problem.

Since there can be no question of undertaking a new Delphi survey of our own, all we can do is to use the findings of several surveys of this nature recently carried out in various countries. These will be found to be a mine of information little explored so far.

While there is no point in describing the Delphi method here(1). its very important advantages should perhaps be underlined:

i) anonymity:
ii) controllable feedback; and
iii) quantifiable responses(2).

The confidential character of the answers is the best guarantee of their sincerity. Inviting respondents to comment twice, i.e. on the statistical results obtained during the first, and subsequently those of the second round, ensures an effective feedback which inevitably leads to an appreciable reduction of initial divergences(3). Lastly, as in opinion polls, the qualitative responses can be statistically processed by simple counting with or without weighting.

Usually the number of experts consulted is about fifty, or at the most one hundred. For instance, a recent Swedish survey(4) concerned with future automation of information services was based on the opinions of fifty specialists. The Center for Future Research of the University of Southern California is carrying out a Delphi survey to determine the social implications of widespread computer utilisation: 68 experts from about ten countries will be questioned.

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1) The method was developed in about 1964 at the Rand Corporation. See T. J. Gordon and Olaf Helmer, Report on a Long-Range Forecasting Study, The Rand Corporation, Santa Monica, California, September 1964.

2) This being approximately the terminology used by O'Neill, Hugh V., A Technology Assessment Methodology - Computers - Communications Networks, The Mitre Corporation, June 1971, pp. 147-48.

3) The danger of this procedure is an undervaluation of some extreme or merely overbold opinions. and therefore of excessive conformity.

4) SAFAD [Swedish Agency for Administrative Development], Report on a Delphi Study - Information, Documentation and Media (English translation, 1971). Complete, original edition: Statskontoret, Information, dokumentation och media. En framtidsbedömning med Delfi-teknik, 1971, 4 volumes.

Special mention should be made of the study Science and Technology Developments up to 2000 A.D., carried out in Japan in 1970(1). In this survey 4,000 scientists and experts were asked about more than 600 technological events. The final report includes a special section on information, from which we shall incidentally be borrowing a number of forecasts.

From these and from a number of American surveys, all forecasts relevant to the knowledge industry and its components can be extracted and then grouped by sectors and/or most likely dates of attainment. In view of the wealth of subject matter the forecasts had to be divided into two parts, one relating to the present and future role of information in research and medicine(3.3), and the other to the potential future role of information in education and culture (3.4). These two sections constitute a whole, however, in that together they give some idea of what the knowledge industry will most likely be like in ten, fifteen, or twenty years.

Despite the great diversity of sources and of the conditions under which the surveys were carried out, this confrontation of European, American and Japanese opinions points to a most remarkable convergence of views(2).

Either opinions coincide totally in regard to some identical technological "event"; or else, opinions converge, but forecasts as to the attainment date may differ slightly, although never by more than two or three years. Or again, the scientists and experts were questioned on different events and/or projects; but even then the opinions expressed are in no way contradictory. Moreover, these opinions, most of which are complementary, are useful for cross-checking purposes.

The degree of consistency of these projections is such that the resulting forecasts might almost be regarded as a scenario. Yet it is a special kind of scenario: first because it was not written by a single author but collectively, as it were; and second, because in a standard scenario the future situation is usually described as the outcome of a logical sequence of events, beginning with the present situation. In our scenario of sections 3.3 and 3.4 the sequence is reversed. Analysis of the forecasts

1) Report published by the Japan Techno-Economics Society (English translation), Tokyo, 1972.

2) We would point out in passing that the overall - and international - consistency of projections from such varied sources enhances the value of Delphi surveys carried out at national level.

yields a certain profile of the future, and it is this profile which constitutes the starting point.

3.3 AUTOMATED INFORMATION AND SCIENCE

The consensus of several hundred scientists and experts is that the future of the knowledge industry and all its components without exception, is closely related to the automation of information. The unanimous view is that during the decade 1980-90 automated information will entirely replace the more or less adequate manual processes at present transmitting and disseminating knowledge.

Only then will information actually become an invaluable, universally appreciated input and a tool of incomparable efficiency for the knowledge industry and for those who work in that industry.

These are the main conclusions brought sharply into focus by all the Delphi surveys. The detailed forecasts to be found in these surveys are no less interesting and contain some surprises.

We have re-arranged these forecasts by subject or theme and. using Professor Machlup's definition of the knowledge industry as a base, we nave adopted the following sequence: science, research, technology(1); medicine, health; education, training and culture. For each event or project we shall indicate, in brackets, the most likely date of achievement, which is usually the median date and sometimes the arithmetic mean of the opinions collected.

Contrary to a commonly accepted view, the vast automated information networks of the future will not come about by a mere extension of the few rudimentary systems now existing, nor in such hitherto preferred media as magazine articles or descriptive bibliographies.

In the future, preference presumably will be given to scientific and especially technical reports which will be analysed by specialised data banks (1979). Other data banks will then centralise abstracts of Ph. D. theses (1979); then industrial patents will be catalogued and condensed for computer storage (1980); later (1987), they will be recorded in full and made directly accessible by means of a specialised, comprehensive thesaurus.

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1) It should be noted that when the experts consulted in the "Delphi" surveys speak of scientific, and in some instances technical information, they are referring to items of knowledge that relate either to R & D type research, or to technology and industrial applications.

The second wave of automation on an industrial scale will involve technological information and especially technological data (1985). The data banks and analysis centres responsible for collecting, processing and re-issuing technological knowledge will, we are told, be organised by branch and/or speciality. These centres will be in a position to supply, on an exhaustive or selective basis, information and auxiliary material in the form of relevant statistical tables, drawings, graphs and models (1985). All these items will be constantly checked, amended and updated (1986).

Automation will then spread to other sectors, finally embracing all forms of communication. However, scientific documents will not really circulate freely for everyone's benefit until the automatic translation of scientific and technical material has been fully developed (1987). Subsequently (1994), the full text of about 50 per cent of all scientific literature will be stored in computers and thus made accessible according to requirements.

Not until this third phase will the majority of scientific/technical libraries and information centres be re-organised and effectively adapted to the new procedure. Once they are almost entirely automated (1987), they will in fact become a selfservice facility, since each item of information requested by any user can be automatically extracted from enormous, highspeed memories, projected on a screen and reproduced upon request (1987). The general public, just as the specialists, will have access to the libraries, information centres and even to the archives of newspapers and radio and television networks, through the use of videophones, and everyone will receive increasingly comprehensive and personalised service (1987).

In the field of medicine, the main effort will undoubtedly be concentrated on improving the accuracy and speed of diagnosis(1); for diagnosis constitutes the basis of the treatment to be prescribed in each case, and the basis of all future medical progress, precisely through the accumulation of massive sets of clinical observations and their processing by computer. The volume of data to be collected, recorded and analysed is in fact so great that only very powerful automated systems can perform these functions. Given this general outlook, the experts foresee a number of intermediate stages.

1) "... diagnosis is what is important in a medical information system." Cf. Caceres, Cesar A. and Anna Lea Weihrer, "Information Science Applications in Medicine"; in Annual Review of Information Science and Technology (Carlos A. Cuadra, ed.) Vol.6, 1971. op. cit., p. 326.

Simple medical analyses will be automated very soon (by 1975). Automation will then gradually include the recording and handling of medical index cards and questionnaires, checking each patient's medical history, the clinical examination itself (19[illegible]), and will culminate either in the assisted or almost fully automated diagnosis (198[illegible]). Teleprocessing and audiovisual aids will later (1985) enable clinical examination and diagnosis to take place by remote control.

Check-ups will also be performed by computer (1985), which in addition will handle without any difficulty all administrative records, formalities and procedures. As a result the activities of medical personnel, primarily doctors and nurses, will be reduced or channelled in other directions (1985).

In hospitals and nursing homes a radical re-organisation and redistribution of tasks must be expected. The different hospital centres will be required to specialise, in view of the increasingly sophisticated types of treatment they will be providing (1988).

The efficiency of all these facilities, will of course, depend on the techniques used in collecting primary data, and on the completeness of the clinical and medical data stored. The collection of medical data can be automated fairly soon, in the United States by 1976. While the first big medical data banks will be established locally (1986 or 1987), they will be interconnected almost immediately (1988). These data banks will be assisted by a world information centre (1988) which, we are given to understand, will co-ordinate and exchange the most varied types of information.

At the other extreme of this future system, videophones and closed-circuit television will provide a direct communication link between the patient and his doctor who, before the end of the century (1997), will be able to make his diagnosis without actually seeing the patient.

3.4 AUTOMATED INFORMATION AND EDUCATION

The decade 1980-90 will see the gradual but eventually massive penetration of automated information into the vast fields of education and culture. This revolution, the experts assure us, is inevitable as it will be imposed by the unprecedented size of the problems which will face universities, schools and education in general.

In the United States alone, the number of students in universities and colleges rose from 2.6 million in 1955 to 5.5 million in 1965, and is expected to reach 9 million by 1975(1). Longer schooling accounts for the increased number of students in primary and secondary educational establishments, which by 1968 stood at no less than 52 million(2). The same pattern occurred simultaneously in all other OECD Member countries.

To this quantitative explosion must be added the difficult but essential problem of adjusting teaching methods to the expansion of new knowledge. It is also becoming increasingly necessary to organise education on a continuing basis so that adults may have access throughout their working lives to constantly enriched knowledge.

Under the combined pressure of these forces, educational "needs" tend to double in less than ten years. In the longer term the growth of student enrolments will admittedly drop, but the number of adults to be retrained will increase exponentially. Furthermore, allowance will have to be made for the tendencies towards greater specialisation and the foreseeable development of multidisciplinary studies.

It is against this background that the forecasts concerning automation (at least partial) of education and vocational training must be seen. The first step in this direction will be taken when the computer can select the curriculum and subject matter to be taught and adapt it to the learners own "profile", i.e. pupils at progressive secondary schools (1978) or adults enrolled in refresher courses (1977). New textbooks will make their appearance (1972-80) in the form of microfiches or microfilms, whose contents can easily be updated as required.

Faculties and university institutes will be linked to data banks and processing centres (1983). Later each student will have a videophone that can be connected with any of these networks (1986).

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1) K. A. Simon and M. G. Fullam, Projections of Educational Statistics to 1975-76, United States Department of Health Education and Welfare, Office of Education, Washington, D.C., 1966, p. 8.

2) Innovation in Education: New Directions for the American School, Committee for Economic Development, July 1968, pp. 66 et seq. See also United States House of Representatives, Committee on Science and Astronautics, A Study of Technology Assessment, July 1969, Appendix A ("Data Base for Technology of Teaching Aids"), pp. 107-42.

Meanwhile new audiovisual teaching aids, using advanced simulation techniques, will have been developed. These aids will be designed both for students receiving general education, beginning with the primary and secondary schools (1985). and those enrolled in specialised courses: languages. rehabilitation of handicapped persons, car-driving (1981). specialised medicine (1983). etc.

Dissemination of these new techniques seems likely to occur rapidly. They will soon (1984) be as widespread as static audio-visual methods are at present. For example, 50 per cent of higher engineering education will be given through the automatic data-processing facilities of universities (notably in the United States. some time between 1974 and 1983).

Under these circumstances the role of school and university teachers will change considerably. The teacher will become essentially an organiser; he will co-ordinate studies centred primarily on practical applications, and organise and supervise the student/machine dialogue (1984). The pupil or student will do more of his work - perhaps up to 50 per cent - at home, where he will have a terminal and closed-circuit television at his disposal (1989 or 1990). Before the year 2000 electronic terminals installed in houses and apartments will be as common as private telephones (1990).

Parents will, of course, be able to use this equipment for their own instruction: some to further their occupational training by simulation (from 1983), others for infant care (1980), and yet others for general knowledge purposes (1990).

The automated systems of the future will also make it possible to develop the child's creative gifts at school (1983). Teaching methods based on the same principles and relying on the same techniques will be used in introductory and/or training and refresher courses for company employees (1982).

While the acquisition of encyclopaedic knowledge will thus lose a great deal of its importance, encyclopaedic data will nevertheless be stored in computer memories and held available for use by young and old alike in the form desired: by projection onto a screen, or with the aid of a video device, printed, or reproduced, with all the required illustrations (1986). The public will have remote access to museums, exhibitions, cultural events of all kinds and to the most varied sources of cultural, scientific and technical information. In this way, all the conventional media of communication - press, radio, television, publishing - will be used directly and continuously for training and education, for progressively raising cultural standards, and for organising entertainment and leisure activities. But they will have to pay for it through radical transformations. For example, the publishing industry will have to change over largely to micropublication and "custom-made reproduction", by using miniaturised media such as microfilms, microfiches, facsimiles, etc.

Expenditure by households for education and culture will rise steeply, and about half of the money spent (1990) will go towards the acquisition of knowledge in its widest sense with the aid of the electronic devices just described. Some claim that the outlay will amount to as much as an average American family now spends on automobiles(1).

3.5 QUANTITATIVE EVALUATION OF THE DELPHI FORECASTS

The median predictions taken from the Delphi surveys (3.3 and 3.4), when considered as a whole, indicate for the knowledge industry alone some 40 projected automated information systems, each designed for a different application. Of this total, about four-fifths would be operational by 1985 or by 1987 at the latest, i.e. during the fifteen years which are our particular concern.

The future systems, which have been predicted with impressive unanimity, would thus be, roughly speaking, a hundred times as many as those of today. The lowest estimates postulate an increase by a factor of 50, in this case including pilot experiments and systems now being established.

Is such an expansion feasible? Is it even conceivable? Assuming it is the result of uninterrupted exponential growth, this would still mean an annual increase of either 30 per cent or 36 per cent.

Performances of this order, extreme though they may appear, have in fact been achieved over ten to fifteen year periods, notably in the field of automatic data processing, both as regards the number of computers in operation and that of EDP staff

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1) John McHale. "The Changing Information Environment: A Selective Topography", op. cit.

employed. For example, the annual turnover reported by computer manufacturers in the United States rose from $975 million in 1959 to $10.6 billion in 1969, an annual growth rate of 27 per cent(1). Even so, it should be remembered that during the previous decade the rate was appreciably higher. The Canadian Federal Government has for a whole decade spent sums on administrative EDP which have risen 30 per cent or more annually(2).

Specialists at the Mitre Corporation predict that, between 1970 and 1980, systems integrating computers and telecommunications will be established with breathtaking rapidity. According to their forecasts, the number of existing installations will rise by a factor of 200 in a decade - the exponential growth rate consequently being superior to a cumulative annual growth rate of 69 per cent(3).

Many more examples might be mentioned. While these precedents prove little, they do show - *and this is the important point* - that steady growth at a yearly rate of 30 per cent is indeed possible.

To assess the likelihood of the forecasts provided by the Delphi surveys, we can test the implied growth rates by comparing them with business forecasts made by manufacturers of the various types of equipment which will be required by users of automated information systems ten or fifteen years from now. We can also compare such implicit growth rates with forecasts independently carried out for telecommunications, the essential media for transmitting information/knowledge. As a cross-check we can finally use forecasts relating to the number and value of terminals.

According to Eastman Kodak, the turnover of the microform industry in the United States rose from $2 million in 1957 to $29 million in 1967, and is expected to reach $390 million in 1980(4). Two slightly different estimates are available for

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1) Hugh V. O'Neill, A Technology Assessment Methodology - Computers-Communications Networks, op. cit., p. 78

2) OECD, Committee for Science Policy, Report of the Ad Hoc Group on Information, Computers and Communications (reference SP(71)9, dated 25th June, 1971) - also called the Whitehead Report, p. 9.

3) Hugh V. O'Neill, A Technology Assessment Methodology - Computers-Communications Networks, op. cit., (Summary), p. xii.

4) Nelson, Carl E., "Microform Technology", in Annual Review of Information Science and Technology, Vol. 6, 1971, op. cit. pp. 78-94.

microfilms; sales amounting to some $400 million in 1970 would reach either $1.7 billion or 2.1 billion by 1975. The value of equipment used for producing, reproducing and handling microfiches in 1969 was estimated at $4 million, and is expected to reach $82 million by 1975.

In his study on computers and telecommunications, Kimbel(1) quoted the following data from the Datran Report. In information services alone the number of termination points would increase from 32,000 in 1970 to 505.000 in 1980; the number of data terminals from 45,000 to 791,000; and the number of communication transactions from 0.6 billion to 56.6 billion.

According to another estimate by the Diebold Group, the total number of terminals in the United States would rise from 30,000 in 1965 to 2 million in 1975, the sales value increasing from $100 million to $5.5 billion(2).

From these data the respective yearly growth rates can easily be calculated. The rates thus obtained are shown in Diagram 9, plotted on a semi-logarithmic scale to facilitate comparison. The years expressed as abscissae are numbered from 0 to 15, and the period corresponds approximately to 1970-1985 or 1972-1987(3).

The rates range from a minimum of 22 per cent to a maximum of 66 per cent most of them being within a fairly wide bracket, i.e. between slightly more than 30 per cent and slightly less than 50 per cent.

Lines F and G on this Diagram show the range of the Delphi forecasts (taken together) in regard to the installation and widespread expansion of automated information systems to meet the general needs of the knowledge industry between 1970-85 or 1972-87. Line F shows the low assumption, i.e. a constant geometric progression at a yearly rate of 30 per cent, meaning that installations would be multiplied by a factor of 50 in 15 years. Line G shows a yearly geometric progression of 36 per cent, i.e.

1) Kimbel Dieter, Computers and Telecommunications, OECD, Paris 1973. See also Datran Report, in Richardson, John M. and Roberts Gary (Ed.), A Preliminary Survey of Data Communications in the United States OECD Document DAS/SPR/70.66, 4th November, 1970).

2) Problèmes Economiques, No. 1192, 5th November, 1970, p. 15.

3) While such a procedure is commonly used, it may be somewhat arbitrary. This is because the original estimates refer to dates and periods which are not strictly identical. Generally the period considered was 10 years, but exceptionally longer and shorter periods may be found, extending from 5 or 6 to 23 years. These differences are clearly indicated on the Diagram.

multiplication by a factor of 100 in 15 years, hence corresponding to the high assumption.

Diagram 9 shows that the range of Delphi forecast values bounded by curves F and G lies at the lower end of the range covered by the commercial forecasts mentioned above. The Delphi forecasts thus appear moderate compared to the commercial ones, whereas originally, and considered in absolute terms, they might have seemed exaggerated and over-optimistic. It can also be seen that the range of forecast growth represented by the angle between F and G is significantly narrower than the range of commercial forecasts. Clearly all manufacturers of terminal and microform equipment expect the market to expand strongly, but their estimates of its potential growth vary widely.

The growth targets suggested for the mid-80s by the experts involved in the various Delphi surveys coincide fairly closely with manufacturers' objectives for as early as 1980 or 1981. As a whole the Delphi forecasts may be regarded as plausible, likely and realisable.

One may add an interesting post scriptum to these conclusions. In an in-depth study based essentially on extrapolation, a group of American researchers estimated in 1969 that in the United States alone between 50.000 and 75,000 automatic information systems would be operational by 1980, against 2500 systems in existence in 1966. In other words, existing installations would be multiplied by a factor of 20 or 30 in 14 years, creating an exponential growth rate between 24 and 27.5 per cent per year. The FCC presently works according to these statistics(1).

Recognising the earlier stage of development of automatic inform tion systems in other parts of the world, the rate of progress in the automation of information will probably be greater in the industrialised countries as a whole than in the United States alone. Finally, the estimates obtained through extrapolation coincide perfectly with the overall predictions derived from the various Delphi studies.

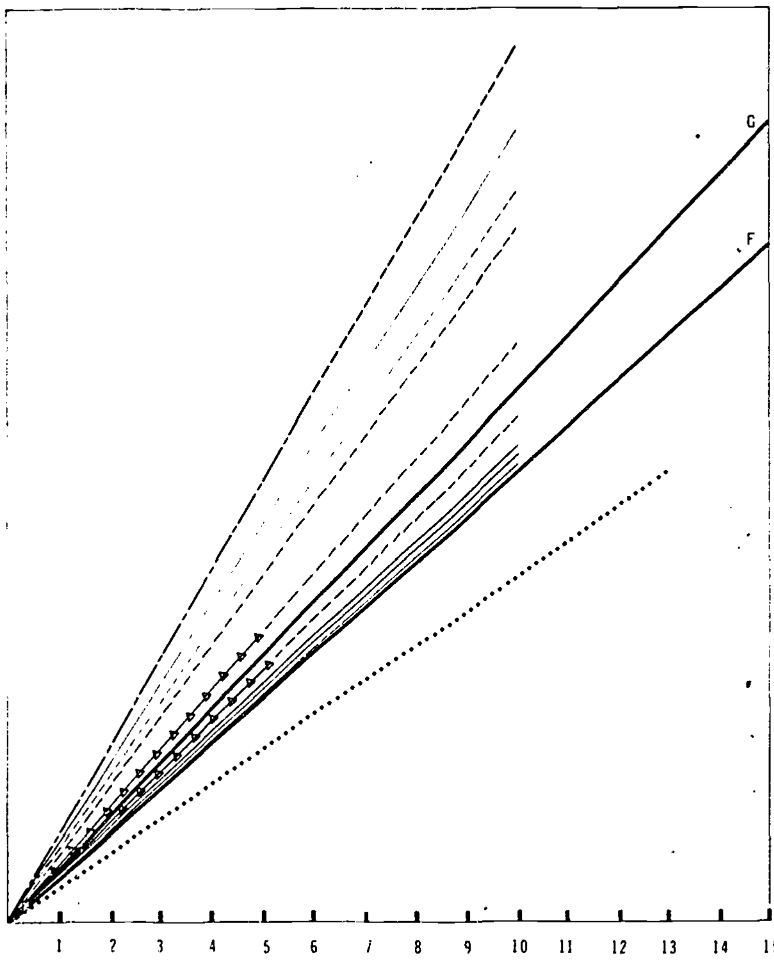
3.6 UNIT COST CONSTRAINTS

The aggregate forecasts in the Delphi surveys permitted us to plot the profile which the knowledge industry might present in the next fifteen years. Then we tried to test their probability

1) O'Neill, Hugh V., A Technology Assessment Methodology - Computers-Communications Networks, op. cit., p. 68

Diagram 9

MAXIMUM AND MINIMUM DELPHI FORECASTS
CONCERNING INSTALLATIONS OF AUTOMATIC INFORMATION SYSTEMS
COMPARED WITH BUSINESS FORECASTS
BY TERMINAL AND MICROFORM MANUFACTURERS
1970 – 1985 / 87



Sources :

- Value of microfiche equipment (Estimate quoted by Nelson)
- Information services in the United States terminal points served, terminals installed, volume of transactions (Datran Report)
- Installed terminals and sales value (Diebold Group)
- Quantified Delphic forecasts
  - F Low assumption yearly rate + 30 per cent
  - G High assumption yearly rate + 36 per cent
- Turnover of microform industry (Eastman Kodak estimate)
- Microfilm Production (Nelson and Yerkes forecasts)

by comparing them with manufacturers' expectations. The primary question to be answered now is: what magic formula will bridge the huge gulf between our present humble achievements and the prodigious feats heralded for 1985 or 1987? More specifically, by what process or mechanism will the transition be made from an index of 1 or 2 to an index of 100?

An automated information system may be set up for such reasons as prestige, safety, air-traffic control, etc. But these are extreme cases. The conditio sine qua non for setting up automated systems on a vast scale is that at a given time the electronic transfer of knowledge and information becomes more economically advantageous than manual or mechanical processes.

The key to the problem lies in variations of the respective costs, and more particularly of unit costs(1). Technological performance and evolution are of decisive importance here. The interplay of the main variables may be outlined as follows:

While the mass of information grows exponentially, technological efficiency - capacity and performance - also grows exponentially but distinctly faster. Hence, unit costs decrease exponentially and almost as rapidly. The main difficulty is to estimate correctly the difference at various moments in time between these two rates, i.e. between the growth rate of the volume of information and the cost of its collection, storage and transfer, and the rate at which the unit cost of the automatic processing of this information decreases.

In 1945 the cost of one million arithmetical operations on an electric calculating machine was about $1,000(2). The first generation of computers reduced the cost to $10. Ten years later the same operation cost only $0.05; in 1975 it will be less than $0.006. In the space of some 20 years the unit cost of automatic data processing will have steadily diminished by a little over 30 per cent each year(3).

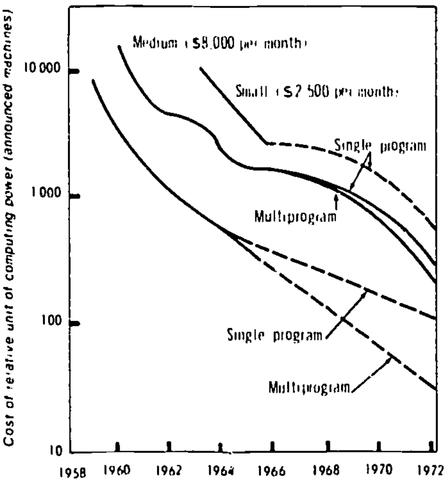
1) The problem that arises is akin to that of the exponential growth of the volume of information available (2.5). The basic explanation for this growth process lies, as we have seen, in long-term increases in productivity of creators/authors of knowledge/information, productivity being in direct relation to the marginal cost of research and that of the information thus created.

2) At the rate of 16 operations per minute and wage rate of $1 per hour; the time required was then one month.

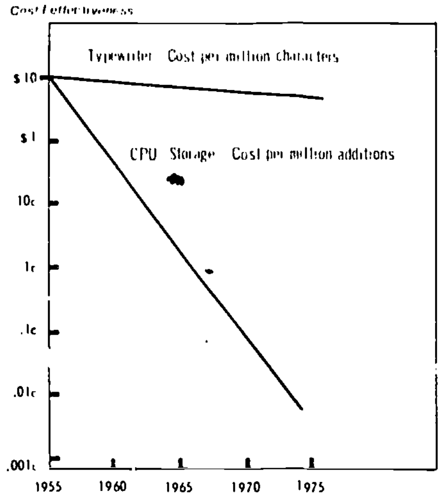
3) John McHale, "The Changing Information Environment: A Selective Topography", op. cit., pp. 4 and 5.

Diagram 10

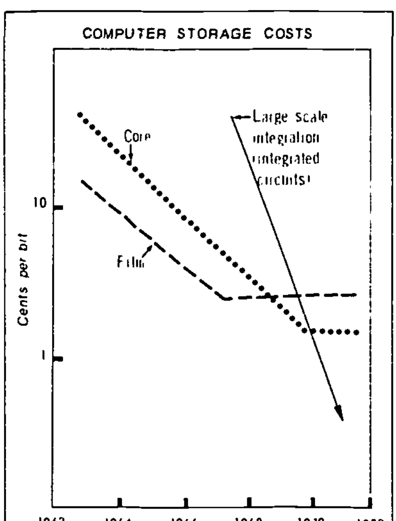
DECREASE IN UNIT COSTS OF AUTOMATIC INFORMATION PROCESSING
VARIOUS EVALUATIONS AND EXTRAPOLATIONS

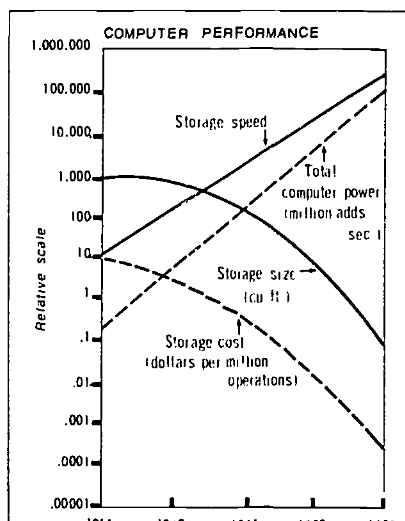


Source: Arthur D. Little Inc.
Trends in cost of computing power.
From: John F. Magee, Industrial Logistics, McGraw-Hill, Inc., 1968, p. 164.



From: W.F. Sharpe, The Economics of Computers, Columbia University Press, 1969, p. 323.





From: John McHale, "The Changing Information Environment A Selective Topography", in Information Technology: Some Critical Implications for Decision-Makers 1971-1990 New York, N.Y., 1971, p. 4

This has been concisely expressed by an American and a British author(1), who stated that the efficiency of information technology doubles every two years while the cost falls by half (this implying a drop in unit costs of 30 per cent in round figures). The authors did not hesitate to conclude that by the end of the century we should be able to process automatically the entire sum of human knowledge.

Other estimates more or less confirm the earlier evaluations. Some ten estimates are reproduced in Diagram 10. In these graphs a distinction is made between storage costs, which vary depending on the storage medium, and processing costs, where the unit-cost curves are plotted for three computer sizes, with a further distinction between single and multiple programming.

The trend in all these curves is towards a decreasing exponential function and the rates of decrease, assumed to be constant, are located without exception between -40 and -30 per cent. They can be extended by extrapolation beyond 1975, as shown in Diagram 11. We are told, of course, that holographic memories based on the laser principle will come into use before the end of the decade and that a further spectacular drop in costs can be expected. Caution has prevented us from considering this eventuality, but it is reasonable to assume that it is covered by the faster rate of decrease (-40 per cent).

In short we shall assume that the decrease in unit costs during the next fifteen years might be situated in a bracket bounded by curves A and B in Diagram 11, which represent rates of -30 per cent and -40 per cent respectively.

But since the cost of software does not decline in the same proportions, it is likely that the cost decrease will in fact follow a logistic function. Curves A and B would then become A' and B'.

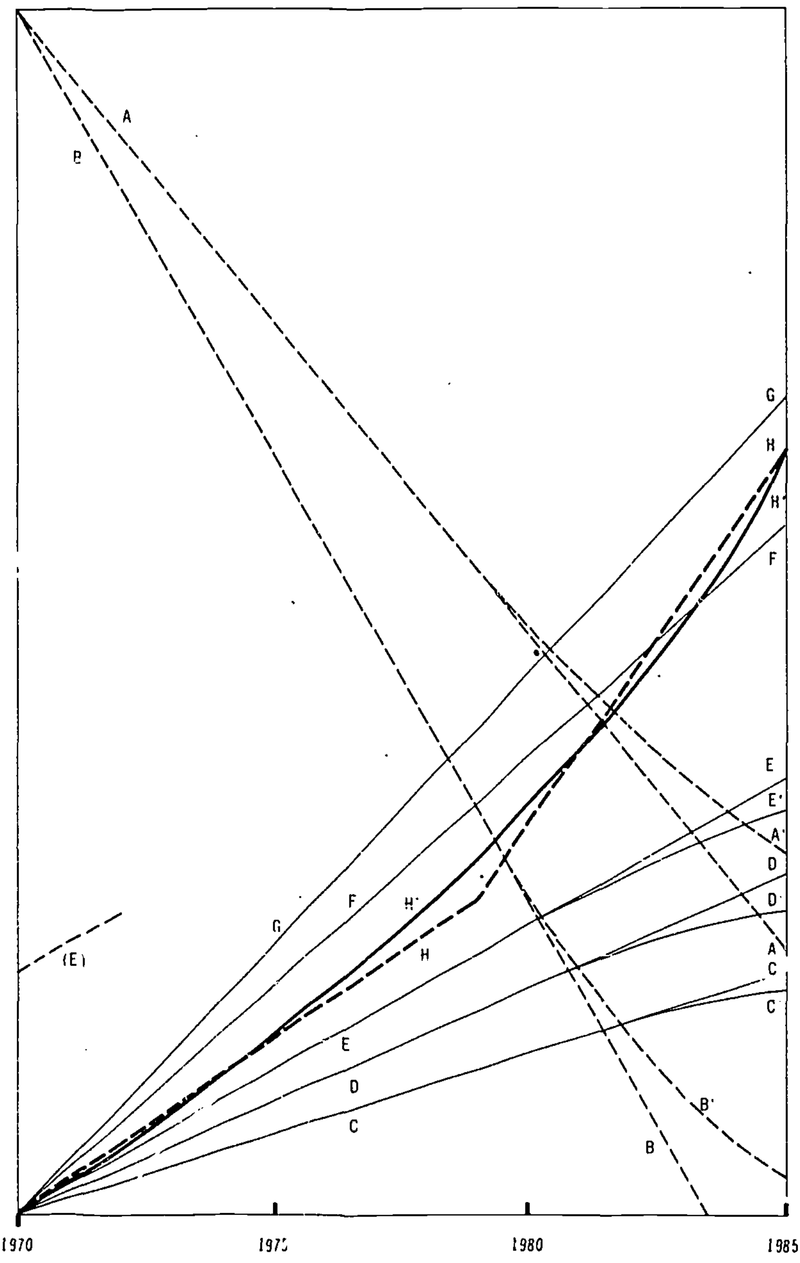
The (rare) illustrations that can be taken from the existing or planned systems lend some substance to this assumption. In 1963-64 an hour of university-level computer-aided instruction cost $2.60 per student(2). One of the aims of the PLATO project,

1) Roger Meethan, "Information Retrieval". Meethan refers to J. C. R. Licklider, Libraries of the Future.

2) At this same time an hour of conventional academic teaching cost $2.75 per student, whereas an hour of ordinary primary instruction cost only $0.30.

Diagram 11

CHART OF THE PROCESS OF SUBSTITUTING AUTOMATED INFORMATION PROCESSING FOR MANUAL AND MECHANICAL PROCESSES: PROSPECTS 1970-1985/87



sponsored by the University of Illinois(1), is to cut this cost to 25 or 30 cents in five or six years. This projection is well within our bracket. The daily cost of the first hospital information systems amounted to $10 per patient hospitalised(2). The most recent systems show a much better rate of performance, with unit costs tending to decrease in line with our working assumption (-30 to -40 per cent).

Let us turn now to the other alternative, the transfer of information by manual and mechanical means. In fifteen years' time the volume of information to be processed will have increased 4 to 7 times(3). This trend is plotted in Diagram 11 by curves C and D and their logistic variants C' and D'.

Handling this huge mass of information will require, in addition to new mechanical equipment, far more personnel. This increase will be almost proportional, as only minimal productivity gains are expected. Thus it has been calculated that under these circumstances the Yale University Library alone will need a permanent staff of 6,000 in the year 2040(4).

Staff costs at present account for 60 to 80 per cent of the budgets of scientific and technical libraries and documentation centres(5). Remuneration is rising by at least 7 per cent a year. Under the combined influence of these factors, staff costs would grow exponentially at a minimal rate of 18 per cent. On the basis 1970=100, the index in 1978 would be 376 and in 1980, 523. This assumption, which incidentally is conservative, is represented in Diagram 11 by curve E and its logistic variant E'.

Theoretically the intersections of curve E (cost of manual processing) and curves A and B (cost of automated processing) mark the time when automated information would prevail due to

1) F.F.Kopstein and R.J. Seidel, "Computer Administered Versus Traditionally Administered Instruction: Economics", <u>HumRRO Professional Paper</u>. Washington University, Washington, D.C., June 1967, pp. 31-67. Cf. also E.N. Adams, "The Computer in Physics Instruction", <u>Proceedings</u>, Conference sponsored by the Commission on College Physics, 1965.

2) Caceres, Cesar A. and Anna Lea Weihrer, "Information Science Application in Medicine", op. cit., p. 339

3) Cf. 2.3 and 2.6 above.

4) Leimkuhler, Ferdinand F. and Anthony E. Neville, "The Uncertain Future of the Library", op. cit. p. 13

5) Wassermann, Paul and Evelyn Daniel, "Library and Information Center Management", in Annual Review of Information Science and Technology, Vol. 4. 1969, p. 418.

being cheaper. Beyond this point of intersection the rapidity of installation of automated systems would depend on the respective trends of curve E and curves A and B. In particular, the personnel strength of the libraries and documentation centres would tend to decrease, or grow more slowly, as manpower is increasingly replaced by hardware and software.

According to Diagram 11, curve E might intersect the A-B bracket in ten or twelve years. between 1980-83. But actually this date is purely fortuitous since the scale of our diagram is (inevitably) arbitrary. We do not know what the real ratio between the unit costs of manual and of electronic information transfer was originally, say in 1970.

We can overcome this difficulty, however. On the basis of the Delphi forecasts, it is possible to determine the point of intersection of curves E and A-B regardless of the scale used, or at least to identify a probable area of intersection. According to the experts, the big automated information systems will begin to be established in earnest as of 1978-80. Given this approximate date, it is easy to adjust the scale of the graph accordingly(1).

The range of the Delphi forecasts is shown in the Diagram 11 by curves F and G(2). These are two functions corresponding to the basic assumption that there will be a massive introduction of automated information systems, the premise being that the facilities of 1985-86 will be 50 or 100 times larger and/or more numerous than those of today.

However, there is nothing to show that this growth must take the form of a regular exponential function or that the expected expansion will take place at a constant rate. It is therefore legitimate to suppose that this trend might follow the broken

1) It is in fact sufficient to shift the set of curves C, D and E (and their logistic variants) laterally, taking as reference their presumed intersection (around 1978-80) with the pair of curves A-B, these remaining fixed. When this shift is made, curve E meets the y-axis approximately at the level of index 4, which. in a manner of speaking, measures the present (1970) unit cost of manual processing. Since the unit cost of automated processing stands (in 1970) at index 1000, the ratio between these two magnitudes is 4/1000 or 1/250. This ratio measures the relative costs of the two information processing technologies when initial investment and overheads are included. In other words, in 1970 the electronic processing of a unit or block of information was approximately 250 times more costly than manual processing. Since hypothetically (by inference from the Delphi forecasts) these two costs should be equal in 1978 or 1980 the obvious assumption is that between now and then the relative unit cost must fall annually by 50 per cent.

2) These curves have already been shown in Diagram 9.

curve H, which rises exponentially, first at a relatively low rate (1970-79), then at a higher rate (1979-85); or else that it follows curve H', which is a doubly exponential function. Either of these curve forms is compatible with the set of Delphi forecasts for the various sectors of the knowledge industry.

3.7 GENERAL CONCLUSIONS

In recent years several hundred scientists and experts, consulted during a series of Delphi surveys, have expressed their considered opinion on the process and organisation of the transfer of knowledge and information, particularly in the fields of research and science, technology, medicine and health services, education and teaching, culture, and mass media. It is in this sense that we may speak of a veritable knowledge industry which would embrace all these sectors and activities.

We have examined the Delphi predictions with care. In particular we have tried to test the soundness and probability of the forecasts, which in any case are largely convergent. But primarily we have endeavoured to evaluate their impact and principal implications.

Our conclusions are many and varied, and in our opinion significant:

i) Before the end of the decade 1970-80 all the essential conditions will have been met for the mass production and establishment of powerful automated information systems on an industrial scale. From that time on, the entire knowledge industry complex will have access to these new facilities and will use them extensively. As a result it will undergo rapid, radical change and its future will then seem very different from what we believe it to be at present.

ii) In terms of numbers and processing capacity, the electronic information systems created to meet the varied needs of the knowledge industry will in 1985-87 be almost a hundred times those of today. However, today's systems will be hardly comparable with those of the future. In any case, multiplication by a factor of 50 by comparison with 1970 seems a reasonable if not a minimum assumption.

iii) The margins of error of these aggregate forecasts are relatively narrow. Automated systems will begin to be set up on a vast scale not later than 1981-83, and the forecasts for 1985-87 mentioned under ii) above would not be applicable beyond 1989-90. Over a fifteen year period such margins of error are negligible.

iv) The massive substitution of automated information processing for manual/mechanical processes will begin independently of official intervention as soon as unit costs of the two technologies will have reached parity towards 1979-80. Before then few spontaneous, unsubsidised automated systems will be set up, but after this date systems will become more numerous and widespread.

v) At first glance we still have a long way to go, since around 1970 the automated transfer of one unit or one block of information cost perhaps 250 times more than an equivalent manual operation. It is this enormous difference which has so far effectively prevented the introduction of automated systems, with the exception of a few specific cases motivated by reasons of State, prestige, security, pilot experiments etc., in other words, by all kinds of non-economic considerations.

vi) This gap is however destined to disappear within ten years or so, since the cost of the new technology in relation to the old decreases every year by nearly half. This decrease in relative unit cost, which, too, is exponential and rapid, is the result of two opposing movements. On the one hand, the mass of information is growing steadily and rapidly and the costs of manual/mechanical handling are increasing even more rapidly owing to rising wages and the absence of any appreciable productivity gains. On the other hand, the efficiency of electronic technology is growing exponentially and even faster, causing an almost parallel decrease in operating costs.

vii) A few sectors will of necessity be quicker off the mark. The unit cost of computer-based education is already approaching the cost of conventional education. Achievements in this field must therefore be expected fairly soon, although questions of quality and familiarisation are still to be overcome. Similarly hospital information may soon be at least partly automated and made more efficient, at a cost fairly comparable to current expenditure.

viii) Generally speaking, the movement will be from simple to complex applications. For instance, in education the first step will be towards the computer programming of university curricula, technical courses, refresher training, etc., with allowance for the variable "profiles" of the students. In medicine, simple medical analyses will be the first to be automated, then clinical examination, and later still diagnosis.

ix) Technical and technological information will be automated more rapidly than strictly scientific information. Technical reports, rather than magazine articles, and technological data and patents, rather than elements of pure science, will have priority, at least initially and certainly until the beginning of the 1980s. Subsequently, this "discrimination" will progressively, but slowly, diminish.

x) The institution of automatic information systems on a vast scale will entail considerable capital investment and operating expenditure Will it be possible to find the necessary funds? There is every reason to believe that under the pressure of public opinion, efforts undertaken especially in regard to health, education, culture and the environment will have to be maintained if not expanded. The main sectors of the knowledge industry will thus have access to financial resources - private as well as public - which will increase steadily and at a higher rate than the GNP of the developed countries. It will be all the easier to channel part of these resources towards automatic information systems since, in ten years' time, this solution will be found to be more economical than the increasingly obsolete and inefficient manual processes.

xi) Meanwhile the documentation services must cope as best they can with the material problems caused by the continual growth of information and, recruit proportionately larger staffs. After 1980 personnel with very different qualifications will be needed. Retraining of staff in service will then become a real problem.

xii) On the basis of the previous analyses we are now in a position to identify, if not the categories of specialists who will be in greatest demand, at least the duties that will need to be performed. First, it will be necessary to organise the monitoring of information on an industrial scale, i.e. the collection, centralisation and validation of primary data and items of information. It will not be possible to automate all these operations at the outset. It will also be necessary to set up a series of relays between the automated information systems, the purveyors of new information and the users of partially processed information. To perform this function it will be necessary to establish a body of "intermediaries" capable of ensuring a continuous, reciprocal and multidirectional feedback.

xiii) At a higher level, the analyst's function will probably develop in three directions: greater specialisation; a kaleidoscopic, fluid, multidisciplinarity rather than the popular static image; and, lastly, towards an ambivalent capacity for analysis and synthesis. For ultimately, the linear concept of one-time information processing must be gradually replaced by the concept of recycling. Only then can a given stock of knowledge and information be constantly and rationally re-utilised in response to infinitely varying needs. Before considering the ultimate resolution of problems of this kind, we must look more closely at the range of requirements to be met.

Chapter 4

THE MORPHOLOGY OF THE GROWTH OF INFORMATION

It is possible to argue at length about the value of a figure, the accurate plotting of a trend line, or the validity of a forecast. One has the right to question a given method of forecasting, to contest a particular hypothesis or to query a system of measures or indices. But it would surely be wrong to deny the evidence and close one's eyes to the changes now taking place.

Increasing quantities of information are being created all the time. They circulate faster and faster. They are accumulating at a rate which, far from showing the slightest sign of slackening, is actually accelerating.

Before we are overwhelmed by this rising tide we will be able, for some time yet, to evade the issue, look for means of escape and adopt stopgap solutions. But after 15 or 20 years the choice must inevitably be between automation and suffocation. In these circumstances there can be no doubt as to the outcome.

We still have to clarify the essential nature of the information process and discover its internal dynamics. This will be our main purpose in the following pages, though we cannot pretend to exhaust the subject.

This fourth chapter is the newest part of our study. It is also the most difficult one since we will, to a large extent, be breaking new ground, studded with pitfalls.

For the investigations about to be undertaken, we need several new concepts which are sufficiently broad, yet operational and manageable, and in particular a comprehensive concept of information which allows for the infinite variety and complexity of demand and supply. We shall, therefore, begin by providing ourselves with these essential tools (4.1).

We shall also have to revise our methods of analysis, and systematically use the matrix method as it is most appropriate for our purposes. We will establish a number of bidimensional and multidimensional tables which will enable us to group a whole series of relevant coefficients and especially qualitative characteristics, and to analyse subsequently the phenomenon and its dynamics.

In successive stages we will move on to morphological analysis. This in turn will culminate in the construction of a multidirectional dynamic model of the growth of information.

4.1 A GLOBAL CONCEPT OF INFORMATION

A recent OECD report which caused some stir(1) emphasized the need to break away from narrow and outdated concepts and adopt a global concept of information. We are naturally of the same opinion. Yet if such a suggestion is to be followed up practically, the concept adopted must be given a concrete content and a clear formulation; also, we must be sh how to use it.

As the authors of the Whitehead Report themselves point out, their approach is not entirely new, since the term "total information concept" was invented by Calder in 1969(2). What exactly is the full meaning of this new terminology? We have the choice among several options.

i) The field of application may first be defined negatively as it were, by comparison with narrower concepts. This is in fact the object of another OECD paper known as the Piganiol Report(3) which states that "we must view scientific and technical information as only part of an immense complex of information".

ii) It is however possible to define the area of application positively, by making a fairly complete list of the sectors and activities primarily concerned. The Whitehead Group adopted this strategy when endorsing the Calder concept: "... computing, publishing, newspaper, broadcasting, library, telephone and postal services..., together with large slices of teaching, of government of industrial

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1) Committee for Science Policy, Report of the Ad Hoc Group on Information, Computers and Communications, OECD Document SP(71)19, of 25th June, 1971, frequently known as the "Whitehead Report".

2) Calder, N., Technopolis, London, McGibbon & Kee, 1969.

3) Information for a Changing Society, OECD, Paris, 1971, p. 17. This Report also lists a few "aspects": economic, social, legal and political, and certain "fields": ecology, environment, public health, modern living conditions, etc., to which this wider concept of information may be applied. Cf. pp. 17 and 30.

and commercial operations, and of many professional activities." Although this is a slightly fuller list, the approach is very close to the concept for the knowledge industry so dear to Professors Machlup and Marschak(1).

iii) Leaving aside the formal aspects, we can concentrate instead on the nature of the information process and draw a few theoretical as well as practical lessons from it. McHale, for example(2), holds that in reality information is primarily a resource. True, since it is not consumable it is a resource of a special character. But information is undoubtedly a factor which enters into any process of creation or consumption of wealth, as well as any decision-making process. Consequently, information is also a link between the most diverse activities of a material and/or intellectual character.

iv) The same idea is reflected in an influential OECD Report, Science, Growth and Society(3) which unequivocally refers to knowledge as a factor of production. By extension, information, being closely related to knowledge, should be considered on the same footing. But from this point of view productive activities occupy the front of the stage, while the intellectual activities of the decision-makers are left in the background.

v) Gorn(4) has chosen a different, largely philosophic, approach, yet leading to roughly similar conclusions. In his attempts to arrive at the essential nature of information, Gorn acquired the conviction that information, with matter and energy, belongs to the trilogy of basic *phenomena* which constitute the foundation of all human activities.

vi) Starting from these considerations, Otten and Debons(5) look towards the advent of a new discipline, a metascience

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1) Cf. under 3.1 above.

2) McHale, John, "The Changing Information Environment: A Selective Topography", op. cit., pp. 1-18.

3) OECD, Paris, 1971, p. 97.

4) Gorn, Saul, "The Computer and Information Science and the Community of Disciplines", Behavioral Sciences, No. 12, 1967, pp. 432-452.

5) Otten, Klaus and Anthony Debons, "Towards a Metascience of Information: Informatology", Journal of the American Society for Information Science, Vol. 21, No. 1, January-February 1970, pp. 89-94. Cf. also: Farradane, J., "Professional Aspects of Information Science and Technology", in Annual Review of Information Science and Technology, Vol. 4, 1969, pp. 403 et seq.

of information which they have dubbed "informatology". The main purpose of informatology would be the study and explanation of interrelationships between information science in the narrow sense and the other sciences. In the Otten and Debons approach there is no question of engaging in pure speculation, even less in semantic exercises since. by begging the question, they promptly draw up a series of practical recommendations for completely recasting the curricula for information specialists.

vii) For the sake of completeness, an original concept of Buckley should be mentioned(1). According to this author, a careful distinction should be made between substance and form, content and the container. True, information could not exist independently of the physical base and the energy flow which carry it. In its essence, however, information is a relationship between sets or ensembles, which though different and varied are always structured. To ignore this duality, and hence the fundamental aspect of information, is to fail to recognise the universality of a particular relationship between sets, and consequently the general validity of information which is essentially multidimensional. This mistaken approach is, in Buckley's opinion, largely responsible for the parochialism which is a feature of all our present systems of automated information.

For our part, we will agree in the context of this study, and more particularly in this chapter, that information is a fundamental resource and as such must be at the disposal and at the service of all: society, institutions and to the same extent, individuals. But as we need a concept which is operational, we will regard information here essentially as input-output in a system of interrelationships embracing all human activities. This is, moreover, in conformity with the concept of interdependence, one of the most characteristic attributes of information.

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1) "Though information is dependent on some physical base or energy flow, the energy component is entirely subordinate... Thus, "information" is not a substance or concrete entity, but rather a relationship between sets or ensembles of structured variety". Buckley, Walter, Sociology and Modern Systems Theory, Prentice-Hall, Inc., Eaglewood Cliffs, New Jersey, 1967, pp.7-48.

The practical value of this concept may be illustrated by the results of an original survey recently carried out in Norway(1). The authors of this study, which admittedly was rudimentary but unique in its kind, used the scoring method, with numbers 1 to 3, to measure the reciprocal and multidimensional impact of 22 branches of industry and services including scientific and technical information as a separate activity. The general results are reproduced in Diagram 12.

A striking feature is the extremely high score obtained by the scientific and technical information sector, which in terms of impact is well ahead of all other sectors. It occupies first place in 57 per cent of the intersectoral relationships taken into consideration and obtains the second best score in all other cases.

4.2 CLASSIFICATION OF PRIORITY SERVICES

Any reasonably complete analysis of information as a resource should be based, firstly, on a survey of present and potential needs, and secondly, on existing and potential future services. Logically, such an x-ray of requirements and inventory of available services calls for division into appropriate categories.

Here, unfortunately, is where the trouble begins, and we must consider ourselves lucky that, at the end of this section 4.2, we were able to draw up a summary typology of existing and/or desirable services and a provisional list of priority objectives.

To be sure, it would be difficult to find a study on automated information which does not make some reference to user requirements or needs. But in most cases reaffirmation of the user's pre-eminence is little more than lip service. Though there is universal agreement with this statement of principle, once the ritual has been accomplished, attitudes begin to diverge.

Some advocate surveys - in order to identify and locate these famous "requirements" - but never carry them out for lack of material means and perhaps of any genuine desire. Others take it on themselves to plot explicitly or implicitly, usually by inference, the "profile" of various user groups and draw up a list of their presumed requirements.

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1) Our special thanks are due here to Mr. A. Disch, of the Studieselskapet for Norsk Industry (Norwegian Industries Development Association), for sending us the results of this survey which was undertaken within the framework of a more general study published under the title Long-term Planning of I & D in Norway, Oslo, 1971.

Diagram 12 NORWAY: INPUT-OUTPUT MATRIX INCLUDIN

INDUSTRIES & ACTIVITIES	Met. Ind.	Elec. Eng.	Chem. Ind.	Tex. & Cloth	Timber	Furn.	Books	Met.	Min. & Quarry.	Elec Sup.
Metals industry		2	2	1	2	1	1	3	2	2
Electrical engineering	1		1	0	1	0	1	1	1	3
Chemicals industry	2	2		2	2	0	0	2	1	2
Textiles and clothing	1	1	3		1	2	1	0	0	0
Timber	2	1	2	1		[illegible]	3	0	1	1
Furniture	2	0	0	1	3		0	0	0	0
Books	1	1	1	1	3	0		0	0	0
Metalurgy	2	1	2	0	0	0	0		3	3
Mining and quarrying	2	1	1	0	0	0	0	3		1
Electricity supply	3	3	2	0	1	0	0	3	1	
Building	3	1	1	0	3	2	0	2	1	2
Shipbuilding	3	3	1	0	1	1	0	2	1	1
Transport	2	2	1	0	2	0	0	1	1	1
Automation and data processing	2	3	2	1	1	0	2	2	1	2
Aerospace	2	3	0	0	0	0	0	0	0	0
Nuclear power	3	2	2	0	1	0	0	1	1	3
Oceanography	3	2	3	0	0	0	0	1	1	1
Regional development	0	0	0	0	0	0	0	1	1	2
Pollution	1	0	3	1	3	0	0	3	2	1
New subjects	2	2	3	1	2	1	0	3	1	2
TECHNICAL INFORMATION	1	3	1	1	2	1	3	1	1	1
Technical personnel	2	3	2	1	1	1	1	2	1	2

THE TECHNICAL INFORMATION SECTOR

Build.	Ship-build.	Tran.	Auto. & Data Pro.	Aero.	Nuc. Pwr.	Ocean.	Reg. Dev.	Poll.	New Sub.	TECH. INFO.	Tech. Per.
2	3	2	3	1	2	2	0	1	3	2	2
1	2	1	3	3	2	1	0	0	3	3	3
1	1	1	3	0	1	3	0	3	3	3	3
1	0	1	2	0	0	0	0	1	1	2	2
2	2	2	2	0	1	0	0	3	1	2	2
2	1	1	1	0	0	0	0	0	2	2	1
1	0	1	2	0	0	0	0	0	1	3	2
2	2	1	2	1	2	2	1	3	3	3	3
2	2	2	1	0	0	2	1	1	1	2	2
3	1	1	3	0	3	2	1	1	1	3	2
	0	3	2	0	1	3	3	2	2	3	2
1		2	3	2	2	3	0	2	2	3	3
3	3		2	1	0	0	3	3	1	2	1
1	2	2		2	3	2	1	1	1	3	3
0	1	0	3		0	1	0	1	3	3	3
2	2	0	3	0		2	1	2	2	3	2
3	3	0	2	1	0		2	2	1	3	3
3	0	3	1	0	1	2		3	0	2	2
1	2	3	1	2	3	3	3		1	3	2
3	2	1	1	3	2	1	0	0		3	3
1	1	1	3	2	1	1	1	2	2		3
2	2	1	3	2	2	3	1	2	2	3	

Opinions also vary, depending on whether they are expressed by (i) scientists who have helped to set up a data processing system; (ii) executives responsible for management of such a system; or (iii) psychologists and sociologists dealing with these problems.

Scientists do not seem to be beset by doubts. Those engaged in information activities frequently tend to generalise according to their own preferences and especially their own personal and professional experience. This feature is common to all the "checklists" specifying the types of service which scientific experts believe an adequate system of automated information should be capable of supplying in the immediate or more distant future.

These specifications are diverse to the point of creating confusion at first sight; while they all contain some measure of truth, each considered by itself is of questionable value. A means must therefore be found to amalgamate these checklists. It is only by such a synthesis, reflecting a certain consensus, that their scope and usefulness can effectively be widened. This is what we will attempt, in comparing three "checklists" chosen for their representative character.

The authors of all three of these "checklists" are intimately concerned with scientific and technical information and with the framing of information policy(1). Diagram 13 is a simple matrix which can be used as a framework for instructive comparison. The first column lists six types of service, all of them data processing applications.

Any computerised information system can therefore be evaluated in terms of its ability to supply one or more of the following services, each type of service being first rated separately:

i) answers to specific questions;
ii) comprehensive reviews and/or exhaustive reference lists;
iii) browsing;
iv) selective dissemination of information - SDI;
v) introduction to a field of activity which is new to the applicant;
vi) complex syntheses for making fresh assumptions and/or for planning research.

1) Dr. E. Meyer, one of the main architects of several automated chemical information systems in Federal Germany; Peter Judge, Head, Section for Scientific and Technical Information, OECD; and finally, the anonymous authors of a booklet intended for the general public issued by NASA in the United States, entitled: What NASA/RECON Can Do For You, (Washington, D.C., July 1970).

Each of our three authors is presumed to have rated each type of service from 0 to 3. An 0 rating means that the author makes no mention of the corresponding service. 1 is assigned to a given variant indicated in each case. An implicit recommendation is rated as 2, and an explicit recommendation as 3. Our ratings respect the opinion of the authors as deduced from their own writings. The classification of systems is based on the combined score.

None of the six types of services which in theory correspond to the main needs of users has in fact been assigned the same score by the three markers. Generally speaking, however, there was a broad consensus concerning the first four categories while the last two were awarded marks by only one out of the three examiners.

It seems unlikely that these general findings can be usefully elaborated. Diagram 13 already shows a certain divergency of views concerning, for example, the method of compiling bibliographies or the procedures for disseminating selected information ("SDI"), since each expert has his own idea on the exhaustiveness of the bibliographies to be compiled and the criteria for selection. As regards the operational question and answer service heading the list: in chemistry the "permitted" questions should, according to Dr. Meyer(1) break down into nine sub-categories, but unfortunately this classification, to our knowledge, has not been endorsed by any other specialist.

We find similar divergencies among the managing directors of automated documentation services. For example, the managers of the American ERIC system, which deals with educational information, emphasize strict selectivity and the dissemination of knowledge, whereas those responsible for the MEDLARS II system, under the auspices of the United States National Medical Library, stress the supposed needs of research staff. However, neither system has escaped criticism from the practitioners, i.e. teachers and doctors.

The socio-psychologists, for their part, are generally in favour of conducting surveys(2) among existing and potential users.

1) Meyer, Ernst, "Information Science in Relation to the Chemists' Needs" (mimeographed document, n.d.). Table No. 1 annexed includes, under the heading "specific questions", the following nine sub-categories: "Data and physical properties of compounds and mixtures; Chemical and biological properties of compounds; Natural occurrence; Isolation and purification; Preparation and intermediaries; Analysis and determination; Technology and Finishing; Chemical reactions of compounds; Application of Compounds; Application of methods and procedures."

2) Anders, Wolfhart H. and Alexandra Draxler, Toward a Model for Information Dissemination in Educational Technology Responsive Needs. Paper presented to the Steering Committee of EUDISED, Constance, Federal Germany, 28th-29th April, 1971.

Diagram 13

TYPOLOGY OF MAIN SERVICES SUPPLIED BY
AUTOMATED INFORMATION SYSTEMS,
SHOWING ORDERS OF PRIORITY

Type of service	NASA/RECON	Judge	Meyer
Answers to specific questions	3	2	3
Comprehensive reviews and/or exhaustive reference lists	3	1 Access to leading publications and foreign sources	3
Browsing	2	3	3
Selective dissemination of information ("SDI")	3	1 With evaluation and updating	3
Introduction to a field of activity which is new to the applicant	0	0	3
Complex syntheses for making fresh assumptions and/or for planning research	0	0	3

Explanation of figures:

3 = explicit recommendation
2 = implicit recommendation
1 = variant proposed
0 = no mention

Sources:

U.S., National Aeronautics and Space Administration, What NASA/RECON Can Do For You? Washington, D.C., July 1970. Judge, P.J., The User-System Interface Today: National and International Information Systems. Reprinted from Ciba Foundation Symposium on Communication in Science. London, J. A. Churchill Ltd., 1967. Meyer, Ernst, "Information Science in Relation to the Chemists' Needs". (Mimeographed document, no date); Meyer, Ernst, "Some Discussion Remarks of the German Delegate" at the meeting of the Ad Hoc Group of Experts on Networking on Information Systems, OECD, Information Policy Group (2nd and 3rd February, 1972).

However, their argument is weak on several points. So far they have not succeeded in agreeing on how sample surveys should be approached or on the investigation methods to be used: straightforward questionnaire, observation, simulation, motivation surveys, etc.

Moreover, certain "needs" do not emerge until the user's first contact with an operating system or possibly only after repeated experience. Sometimes there is a genuine "feedback" from the system to the user, who is thus made aware of his latent requirements. How can these changes in perception and attitudes be measured and allowed for? The psychologists do not appear to have found a reply to this question, which is of capital importance.

The results of our confrontation of opinions must be regarded as somewhat meagre on the whole. However, the use of even an elementary matrix enables a few new factors to be introduced.

i) In the first place a more systematic approach was found to be clearly necessary, which is quite contrary to individual preferences and a priori choices

ii) The matrix technique proves capable of providing a stricter framework for collective thought; moreover, it acts as a stimulant.

iii) The scoring method - or possibly other methods based on the separate assessment of aptitude, attributes and other qualitative characteristics - may well lead to more objective, balanced methods of marking, and so help to establish a certain order of priority.

4.3 AN OPERATIONS/SERVICE MATRIX

Everyone - expert or layman - has his own, and sometimes a very accurate, idea of what the operational characteristics and performance of manual and especially electronic, information systems ought to be in order to satisfy their users. Suggestions usually refer to speed, reliability of information, degree of specialisation, ease of access, information selection or accuracy. But a great variety of other recommendations which deserve attention have been put forward, to say nothing of the differences of opinion concerning priorities.

What are all these opinions worth? Taken separately, they have no decisive value; hence none of the specifications suggested by any one person can be regarded as absolute, essential or even merely significant. Even when considered at random, they suggest no definitive order of priority. It is as though the variety of opinions forbade rational analysis.

Yet, once a fairly exhaustive list of the operational characteristics mentioned is drawn up and their accompanying value judgements examined more closely, certain affinities among these individual nomenclatures call for attention. Moreover, we find certain operational characteristics that are more frequently associated than others with value judgements such as: imperative, essential, important, useful, desirable, secondary, and so on. In short, it is clearly possible to apply a classification and rating system based on some sort of semantic scale, and even to improve it by a series of tests.

Since it is not possible within the context of this study to undertake such a survey (interesting as it would undoubtedly be), we must omit this preliminary stage and immediately proceed to the following one. We shall therefore assume that a list has previously been drawn up of the operational qualities which users are entitled to expect from any efficient automated information system.

These qualities may be grouped under a number of headings. For convenience we have retained six, distinguishing between:

i) the content of information requested/supplied;

ii) its quality in the widest sense: accuracy, reliability, margins of error, degree of relevance, frequency of up-dating, etc.;

iii) the area covered by such information, including degree of selectivity or, on the contrary, exhaustiveness; level of sophistication or processing desired, etc.;

iv) conditions of access;

v) speed of operation; and finally

vi) the entire range of feedback effects.

Other criteria for classification could, of course, be adopted, but their greater suitability would have to be demonstrated.

The advantage of this method is that it leads directly to the construction of a square 6 x 6 matrix (Diagram 14), showing horizontally the six categories of operational qualities which we have listed, and vertically the six types of services analysed in the previous section 4.2. This table provides a convenient means of exploring a relatively large, but reasonable number of combinations.

Examination shows that opinion is nearly unanimous for only nine combinations or boxes among the thirty-six conceivable ones.

Diagram 14

SQUARE MATRIX : OPERATIONAL CHARACTERISTICS / SERVICES RENDERED

TYPES OF SERVICES RENDERED	CONTENT	QUALITY	SCOPE	FEEDBACK	ACCESS	SPEED
	SPECIALISATION *vs* PLURIDISCIPLINARITY ORIGINAL TEXT AND DATA *vs* REFERENCES ONLY	VALIDITY-RELIABILITY-ACCURACY CONTINUOUS *vs* PERIODICAL UPDATING. DEGREE OF RELEVANCE	SELECTIVE *vs* EXHAUSTIVE INFORMATION LEVEL OF SOPHISTICATION DESIRED BY CUSTOMER	USER/MACHINE INTERFACE DEGREE OF FLEXIBILITY OF SYSTEM USER/ORIGINAL SOURCE FEEDBACK	EASE OF ACCESS SIMPLICITY OF CODE, LANGUAGE ACCESS TO OPEN *vs* CLOSED SYSTEMS INTERMEDIARIES. WITH *vs* WITHOUT	ON-LINE *vs* BATCH-PROCESSING RESPONSE-TIME ADDITIONAL SERVICES (e.g. REPRODUCTION)
ANSWERS TO SPECIFIC QUESTIONS	1	2	3	4	5	6
REVIEWS AND/OR REFERENCE LISTS	7	8	9	10	11	12
BROWSING	13	14	15	16	17	18
DISSEMINATION OF SELECTED INFORMATION ("SDI")	19	20	21	22	23	24
INITIATION TO A FIELD WHICH IS NEW TO THE CUSTOMER	25	26	27	28	29	30
COMPLEX SYNTHESES WITH A VIEW TO NEW RESEARCH HYPOTHESES	31	32	33	34	35	36

EXPLANATION OF SIGNS AND SYMBOLS

Areas of agreement or broad consensus

Controversial areas

vs (versus) = antinomy or dichotomy

Insufficiently explored or critical areas (persistence of serious problems)

Combinations of little relevance or significance

All the other combinations are among either what may be termed "controversial areas", of which there are eleven, or the other thirteen areas, which are called "insufficently explored" or "critical", owing to certain technological, economic, psychological, and other problems for which no solution has as yet been found.

In addition, three areas correspond to combinations of no practical value. The very limited number of these irrelevant combinations suggests by contrast that the square matrix in Diagram 14 contains a large majority of assumptions matching real situations or problems(1).

A few specific conclusions can be drawn from the foregoing matrix analysis.

i) If the various types of service rendered are considered, the major consensus concerns the dissemination of topical information, of which only two aspects remain a matter for argument. These are speed of service or response-time, which remains to be fixed, and the final choice between batch processing and on-line processing.

ii) "Browsingg, which is favoured by many, raises problems on a far larger scale. The solution of these problems will certainly call for long prior technical study, which should be promptly undertaken.

iii) A similarly detailed examination of each of the areas of Diagram 14 may cause some surprise, and even disprove many preconceived ideas. For example, neither the question-and-answer method, nor the automatic compilation of bibliographies can be regarded as adequately specific or developed to give users real satisfaction. And the main reasons for user dissatisfaction are at least partially elucidated.

iv) The evidence shows that the experts have not even begun to give any serious consideration to more complex applications, or to types of services which may become quite common in the future. It would seem that barely ten years after the first automated information systems were introduced, we are already prisoners of a fixed line of thought.

1) Permutations of the matrix in Diagram 14 would p rhaps show certain consistencies of design among different-coloured squares (the familiar "patterns"), in turn suggesting a certain hierarchy of optimal, suboptimal, etc., combinations. This the author has been unable to do in a study of such limited dimensions.

v) If Diagram 14 is scanned vertically it becomes immediately evident that the largest number of shaded or hatched areas comes under the heading "feedback". It is indeed here that the most serious problems are to be found, now and for some time to come. Again, matrix analysis has permitted a preliminary sifting of these problems.

4.4 GENERAL SPECTRUM OF INFORMATION

The goal set at the beginning of Chapter 4. can now be seen more clearly. This is the definition of a coherent set of evaluation criteria which can be used as yardsticks either in assessing the adequacy of automated information systems, or in determining the profile of the most appropriate solutions for the future.

Having decided to attribute only a limited value to any individual judgment, even that of a scientist, we have tried to determine the degree of consensus concerning various operational aspects, considered first separately and then together. From there we have deduced, by inference, certain orders of priority for types of services and methods of operation. This is a step forward from anything so far achieved or suggested.

The goal has been only partly reached, however, as in the process we have discovered the existence of vast areas of indetermination as well as the inability of experts to envisage other solutions than those already known.

Hence two questions arise simultaneously.

i) Should not some other approach be attempted, one which is more objective, less subject to the vagaries of individual or collective human judgment?

ii) Could not a more systematic method of exploration be used capable of providing an overall rather than foreshortened view of all possible solutions?

It seems possible to answer both questions in the affirmative. Our new approach will be dictated by the logical imperative and practical necessity of accounting for every type of possibility and constraint: political, social, institutional, technological, conceptual, etc. In these possibilities and constraints it is in fact possible to see a set of determining factors which jointly foreshadow and define what automated information systems should be like.

It is in the light of these considerations that our new method, i.e. morphological analysis, will be used.

Our approach is illustrated by Table 5, containing a reasonably comprehensive list of possibilities/constraints regarded as a set of parameters and variables; by Diagram 15 which shows the network of relationships existing within this set; and by Diagram 16, which provides a structural picture of the general information spectrum - or universe. These illustr tions and the procedure followed call for several comments.

i) The determining factors shown on Table 5 are intentionally formulated in general terms. They are meant to represent significant, distinct, yet continuous categories, separated only by flexible boundary lines. As each of these categories forms an inseparable whole, it is possible to visualise a series of subsystems in a closed loop. The total spectrum also has the properties of a closed loop.

ii) There is no reason why, if necessary, each category should not be subdivided into subcategories and then into sub-subcategories. For example, the group of exact sciences would be considered to consist of half-a-dozen major scientific orientations, which in turn would be made up of the different specialised disciplines. The coercive power could be broken up into such subcategories as police, immigration authorities, law, courts of law, prisons, etc. The co-operative power would cover such interest groups as trade unions, producers' federations, consumer associations, pressure groups, technocratic power and so on. While the process may be taken as far as desired, we should bear in mind that the possibilities of analysis are not unlimited and that marginal returns diminish as the analyses become more refined.

iii) All the determining elements have been grouped under six broad categories, i.e. objectives, resources, tools, institutions, individuals and values, which together form both the frame and boundaries of the information universe. Both frame and boundaries are seen here, and elsewhere, as flexible. The resources subuniverse, for example, combines possibilities/constraints in respect of hardware, software, telecommunications, exact sciences and human sciences, and basic data. The tools

Table 5

LIST AND TYPOLOGICAL CLASSIFICATION OF POSSIBILITIES AND CONSTRAINTS AS DETERMINING ELEMENTS OF COMPUTERISED INFORMATION SYSTEMS

Generic categories

Objectives
Resources
Tools
Institutions
Individuals
Values

Objectives	Resources
Space	Hardware
Environment	Software
Quality of life	Telecommunications
Standard of living	Exact sciences
Emancipation	Human sciences
Participation	Data
Tools	**Values**
Concepts	Political authority
Models and theories	Economic authority
Explanation	Social system
Forecasting	Ideology
Control	Co-operative authority
Utilisation analysis	Coercive authority
Institutions	**Individuals**
Community institutions	Citizens
Educational institutions	Workers/consumers
Family institutions	Managers/administrators
Specialised institutions	Practitioners/technicians
Production units	Researchers
Distribution units	Multidisciplinary teams

subset is a kit of intellectual instruments, which is in fact common to every scientific exercise(1).

iv) The list in Table 5 contains no reference to the different types of service or to operational characteristics(2). This omission is voluntary as well as inevitable, since they are a component part of the solutions which must be determined.

v) We have had to abandon the idea of introducing any hierarchical principle or order into our construction(3). This realistic attitude has been dictated by our inability to define any general cast iron rule to determine, for instance, whether aims should take precedence over ends (institutions and individuals) or vice-versa, objectives over values, and so on.

vi) Since initially we are incapable of establishing any degree of priority, we must construct our model, at least to begin with, exclusive of linear relationships, as shown in Diagram 15. If all internal and external relationships for each subset are counted, a total of 630 two-way inter-relationships is reached. This figure, which naturally refers to a hexagonal construction is relatively large; more simple, it means that exhaustive analysis should cover as many as 630 theoretically possible combinations. Any further division would only increase this number more than proportionally(4). But even at this level of complexity a complete analysis would be possible only by computer.

1) See in this connection Lipetz, Ben-Ami, "Information Needs and Uses", in Annual Review of Information Science and Technology Vol. 5, 1970, op. cit., pp. 3-5.

2) These aspects were analysed in sections 4.2 and 4.3.

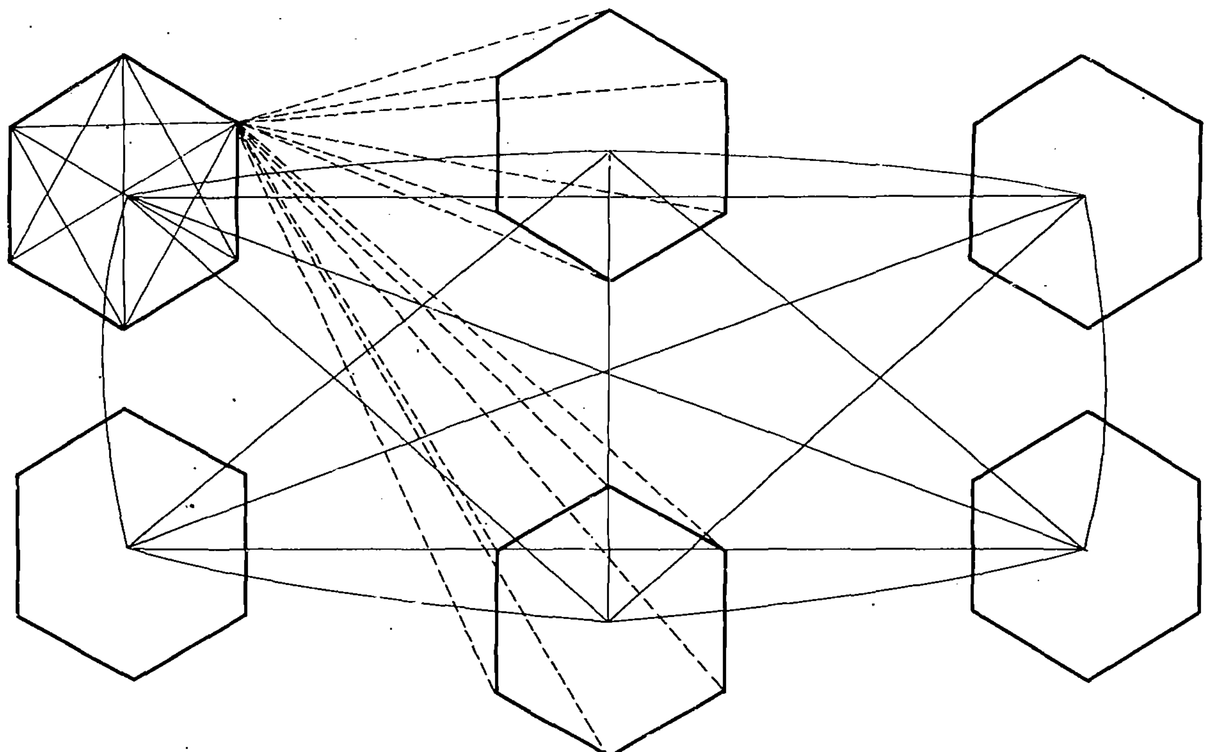
3) In a somewhat different context Professor Samuelson recommended a diametrically opposed approach, i.e. "precedence analysis, distinguishing in turn constraints, main components (data bases, relays, terminals, etc.), structural features, indicators of performance, and finally resulting specifications. But he failed to expand on his suggestion and only plotted an outline. Cf. Samuelson, Kjell, Systems Design Concepts for Automated International Information Networks. The Royal Institute of Technology, Stockholm, Sweden (reference IB-ADB 69, no. 19, s.d.) pp. 1-6.

4) According to the general formula:

$T = n^2\{(N-1 + N-2) + \ldots + 2+1\} + N\{(n-1)+(n-2)+\ldots+2+1\}$ where N represents the number of components making up each subset and n refers to the number of these subsets. In the present case, N = n. In the above hypothesis, i.e. N = n = 6, T equals 630. For N = n = 7, T becomes equal to 861.

Diagram 15

SIMPLIFIED DIAGRAM OF INTERRELATIONS
EXISTING WITHIN A SET MADE UP OF SIX HEXAGONAL SUB-SETS



vii) The morphological method which we have just used thus appears to be a significant extension of the matrix method used in sections 4.2 and 4.3 above. Our construction resembles a genuine morphological "box", which actually is a set of matrices corresponding to a space of n-dimensions. To visualise this morphological, box-like structure, a fairly complex illustration is called for as can be seen from Diagram 16. Needless, to say that no precise order is required for the various hexagonal figures, seven in all, i.e. one representing the six broad categories plus six also hexagonal subsets(1).

Our model is now almost complete. Before testing it in practice, we must ensure that it is consistent and compatible with the aim we are pursuing, as well as our initial concepts as defined in section 4.1.

i) The model in Diagram 16 represents the information universe, and its construction corresponds to the general spectrum of the information resource which we identified from the outset with the "global information concept". It may be noted that there is neither incompatibility in the terms, nor any apparent incompatibility in the structures implied by either terminology.

ii) This conformity is based on the principle of a closed-loop construction both for the set and for each of the subsets making it up. To make it applicable to all cases, all the parts of our construction must be assumed to be elastic, in that the categories and subcategories can be adjusted by redefining their content. Where this is impossible, the difficulty should be overcome preferably by subdividing any unwieldy category. The model is sufficiently flexible to allow for such a procedure up to a certain point.

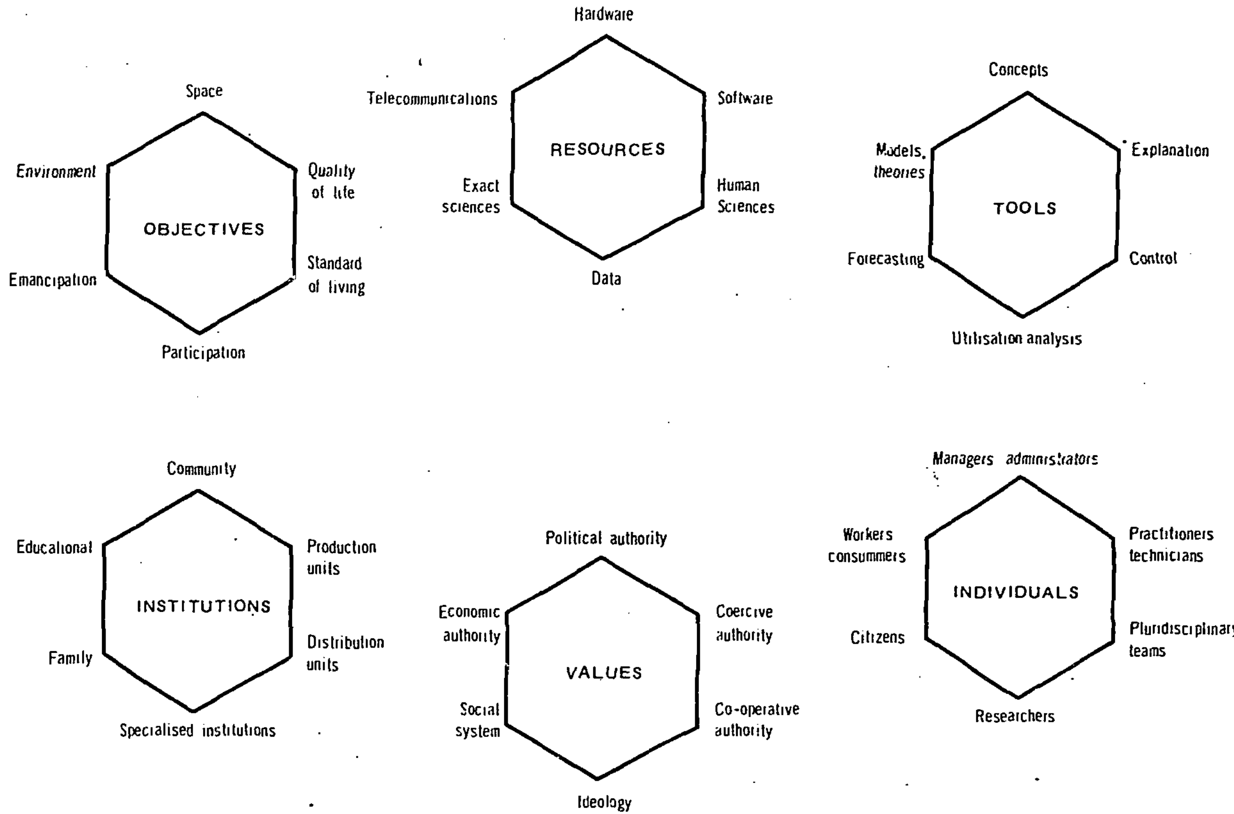
iii) The concept of the closed loop is in fact equivalent to the general continuum principle(2), which means the absence of discontinuities and requires the immediate

1) This construction must in fact be completed mentally by the network of interrelations in Diagram 15.

2) Cf. the same idea though more limited in scope: "All scientific and technological activities from 'pure' research to the development of prototypes can be regarded as a continuum within which meaningful lines of demarcation cannot be drawn, even though different policies are appropriate at different points along the continuum". OECD, Science, Growth and Society, op. cit., p. 70.

Diagram 16

THE GENERAL SPECTRUM OF INFORMATION AS A RESOURCE



removal of any discontinuity which may occur. Let us suppose that it may prove useful in a given context to introduce some new concept. e.g. final objective, mission, means, etc.. This must then be integrated either in one of the existing subsets or dealt with as a component of a sub-set obtained by the process of subdivision.

iv) No undue importance should be attached to the value n = 6, nor to the hexagonal form of our illustration. Both have been chosen purely for convenience. But what we have before us is indeed a general spectrum of the information resource in a universe of n-dimensions.

The next step is to make this model dynamic.

4.5 DYNAMIC MULTIDIMENSIONAL MODEL

We now need to show how the model can be used and, above all, applied when searching for a solution to a number of concrete problems. Our first task, however, will be to make it more manageable, though without changing its structure.

This purely formal transformation has been effected in Diagram 17, in which the information universe is shown in the form of a large circle, while the various subsets are shown as six concentric circular strips. Each strip is further divided into six segments corresponding to the six categories of related possibilities/constraints. All the parts are mobile, in a rotary direction. We can imagine a device resembling a roulette game with (6 x 6 =) 36 numbers. But instead of appearing on a single rotary dial, as in ordinary roulette, the 36 numbers are distributed in groups of six, over six different concentric dials.

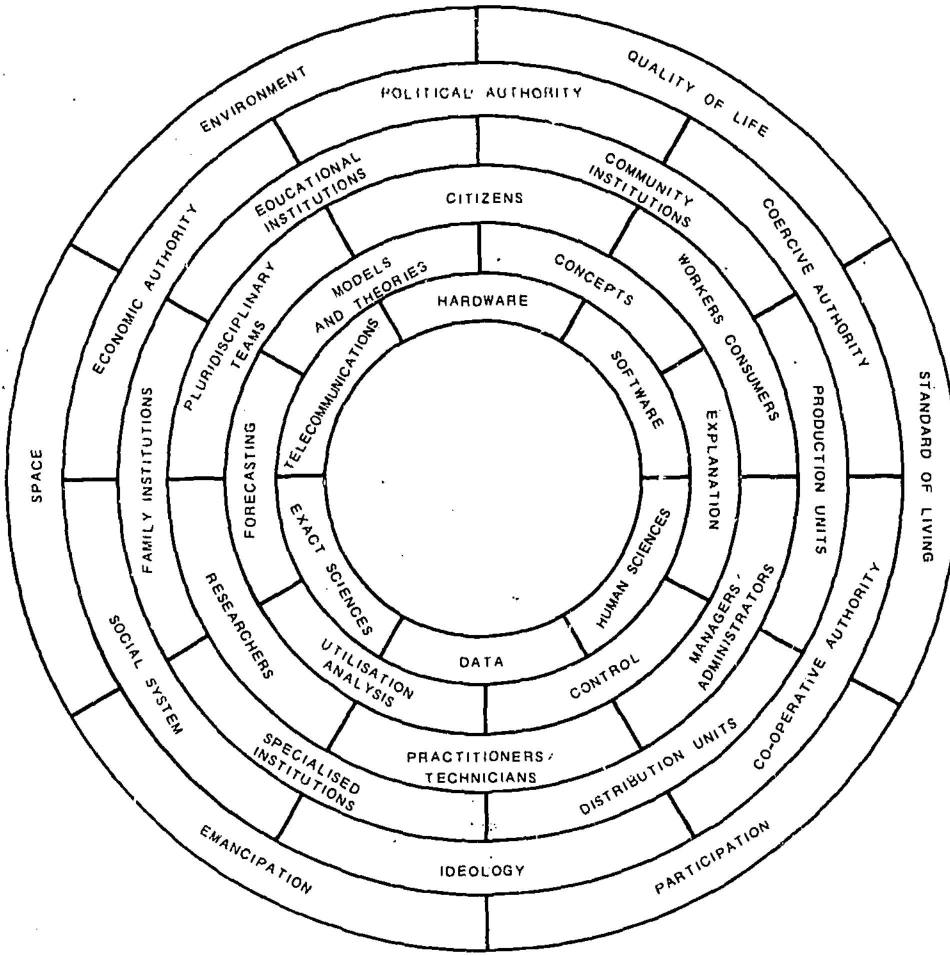
This device may be regarded as a type of model which is structurally multidimensional and at the same time dynamic in design(1).

1) To give credit where credit is due, a multidimensional model was suggested by Richardson and Gary. In that model, which is merely sketched, the "dimensions" are represented by a certain number of intersecting axes, each axis being a kind of scale of values ranging from one extreme "value" to the other. For example, the dimension-axis "ownership" (i.e. ownership of automated systems) covers a whole series of combinations from government ownership at one extreme to private ownership at the other. See Richardson, John M. and Robert Gary, A Dimensional Approach to Policy Analysis, Computer Utilisation Group, OECD Document DAS/SPR/71.26, of 9th April, 1971.

(Footnote continued on page 112).

Diagram 17

DYNAMIC MULTIDIMENSIONAL MODEL OF INFORMATION



The rules have now been fixed and the game can proceed. It is triggered by any change occurring at some point of the system, thus immediately causing the whole set of concentric strips to rotate. At each turn a new constellation of combinations appears on the roulette wheel. For example, the marketing of a higher-performance computer (hardware) promptly affects not only its immediate "neighbours" belonging to the same subset of resources, in this case software, telecommunications, data, exact science and human sciences, but also a certain number of other compartments or segments. Because it is less costly, the computer solution (=automation) may become accessible to an institution, a group of individuals or some socio-economic category, and may also be made to serve one or more new social objectives, and so on.

Let us suppose that the researchers discover the virus of some hitherto incurable disease and, to cure the innumerable patients showing symptoms which may be those of the disease, it is necessary to base the diagnosis by the treating physician on new or very large clinical-data banks. This first "automonous" change in the "researchers" compartment will not only affect the neighbouring "medical practitioners" compartment, belonging to the same subset, but also several other spaces in other subsets, i.e. hospitals (as "specialised institutions"), tools (as "explanation, forecasting"), values (pressure of public opinion on the political authority to provide hospitals with automated information systems on a vast scale); also the resources subset, i.e. new technologies which are induced, software better adapted to demand, larger and/or interconnected data banks, etc.

While this morphological analysis is intentionally summary and incomplete, the example shows how our multidimensional model can initially be used. It is obvious, however, that the various changes induced will give rise in turn to further effects on other parts of

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(Footnote 1 continued from page 110).

However, the solution which we use here must, to a certain extent, be attributed to McHale, John, "The Changing Information Environment: A Selective Topography", op. cit., p.8. McHale's diagram also consists of mo ile concentric circles. Designed to illustrate the "information process", especially its points of impact, it is made up of three intersecting circles corresponding respectively to information as a resource; the technology of information; and telecommunications. The concentric circles arranged around this nucleus represent (outwards from the centre): (i) the impact on individuals and groups; (ii) the impact on politics, business, education and institutions; (iii) global impact; (iv) issues; (v) initiatives. The last three concentric layers are indicated without further explanation.

the spectrum. Cancer research data banks may easily be enlarged to include other data and other clinical measurements; the new technology and the new software will make automation of information economic in other sectors; institutions other than hospitals will benefit incidentally; new types of specialist requirements will be generated, etc.

Let us this time take a simpler example, and limit ourselves to following a single chain of repercussion combinations. If the governments of several developed countries were to include protection of the environment or improved quality of life as one of their priority objectives, a large number of research workers would be induced to abandon their specialised research and join multidisciplinary teams. These would immediately call for complex syntheses of knowledge-information and the relevant input data, and would start to produce new output data which would also be interdisciplinary. This type of service would therefore be rapidly and increasingly demanded of existing and future information systems.

It is symptomatic that this possibility has been seriously considered by only a handful of experts, as we see by referring to Diagram 13. Even these few far-sighted minds have accorded it only secondary status on priority lists. Yet this same possibility, among others, must be apparent after a systematic exploration of the repercussion-combinations suggested by our model. This exploration would moreover draw attention to the problems of specialised personnel, which would result from this particular combination of possibilities/constraints.

Similarly, the need for synthesized information - for example for managers in the private sector and for government administrators - is implicitly but clearly indicated in several matrices in our morphological box. It is easy to imagine that by repeatedly rotating this device, a large number of combinations would be found requiring future automated systems to provide complex information, synthesised, integrated or recycled.

In much the same way our model would yield certain "specifications" which should carry a great deal of weight in the future, such as the superiority of systems open to the outside, i.e. capable of being connected to other systems and therefore compatible with them; or possibly a yet unknown mixed type of information, simultaneously meeting the needs of researchers and practitioners in medicine, biochemistry, engineering, economics and so on.

These few illustrations, provided as guidance, must suffice for the moment. There can be no question here of undertaking a really systematic exploration, which only a powerful computer could in fact realise. This would involve simulation at several levels, since not only the repercussions of the first "round" but also the repercussions of these repercussions several times over would have to be considered. Only then would we see this famous much-discussed "feedback", whose functioning, however, has so far seemed to defy our analytical capacities.

4.6 BUILT-IN ACCELERATING MECHANISM

It is not our intention here to elaborate a general theory of the feedback phenomenon. We will be considering a particular hypothesis, albeit one that has important implications.

We have concluded that information as a resource is a multidimensional universe, highly complex and expanding rapidly. This growth can be partly explained by the mechanical effect produced jointly by several factors or variables: the rapid increase of sources, information, the incessantly growing demand for an ever-widening range of such services, progressive automation of certain transfer operations, greater productivity on the part of the creators of knowledge, etc.

It may however be asked whether this is the whole explanation or whether instead the dynamics of information growth is not due in part to some driving effect or even some autonomous mechanism which would trigger this expansion independently of the presumably decisive variables.

In this connection perhaps something may be learnt from a brief examination of three concepts, which bear a certain resemblance to our hypothesis.

i) The dissemination of an innovation irrespective of its intrinsic merits can, we are told(1) be measured by a "coefficient of attraction". While it is true that the increase in the number of motor vehicles is generally correlated with rising incomes, it has been found that car purchases continue to increase even during periods of economic stagnation, hence regardless of income fluctuations. _Mutatis mutandis_, the generalised use of

1) Lancoud, Ch. et R. Trachsel, "Nouvelle étude du développement probable du téléphone en Suisse", _Bulletin technique PTT_. Berne, Suisse, no. 12, 1963, pp. 1-31.

automated information in one field - say, transport - where this is already economic, could possibly trigger the automation of information in a neighbouring sector where its use is not (yet) economically justified.

ii) Research workers in the Honeywell Company(1) have tried to introduce, in their morphological analyses and relevance trees, cross-support numbers to measure the imitation, or spin-off effect, from one sector to another. But they encountered insuperable practical difficulties.

iii) Some multiplier mechanism seems applicable, at first sight, to the growth of information as a resource. The idea is all the more attractive in that analysis of the multiplier effects of an autonomous initial investment - which might here be a massive research effort - allows for the resultant increase in profits and/or jobs created during successive stages. Another advantage of this method is that it leads, by integral calculus, to a global evaluation of the repercussions, which spread like the concentric ripples provoked by a stone falling on a flat water surface.

Yet none of these three approaches can help us very greatly here, first because techniques have not yet been perfected(2), and secondly because no data and observations of adequate volume and quality are available for estimating such partial measurements as parameters or technical coefficients.

This being so, we can only return to our model in the last two sections (4.4 and 4.5). If the analysis of repercussions which follows some exogenous or induced change is carried further, the rippling movement will be seen to take three fairly distinct forms.

i) The first type of repercussion corresponds to propagation by contagion, of which the following is an example. The banker's profession is to trade in money, and numerical data are his essential material or resource. The volume of book entries is related to economic activity, but it increases more quickly than that activity, since it doubles, notably in Europe, every four or five years. The

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1) Jantsch, Erich, Technological Forecasting in Perspective, op. cit., pp. 219-220.

2) With the exception of econometric applications, notably in the field of consumption, which have proved their worth.

banking system has been able to deal with this extraordinary expansion only by automating payments by cheque, with a time saving of up to 99 per cent and a financial saving of some 85 per cent to 90 per cent(1), then successively by automating transfers, withdrawal notices, credit card payments, etc.

Propagation by contagion is shown in diagram form in figure a of Diagram 18, shaped like a cobweb. The automated processing of a category of banking operations and information has led - through the play of coefficients of attraction whose reality cannot be denied even if we are incapable of calculating their value - to the automation of a whole spectrum of accounting and financial operations; even outside the banking sector: investment funds, insurance companies, stock exchanges, exchange brokerage, etc.

ii) Figure b on the same diagram, on which lines A, B,.....F represent the six possibilities/constraints of any subset, depicts a somewhat different situation. At a given moment, for example, during the second phase, an important "breakthrough" takes place, say in sector B. Immediately segment A_2B_2 deviates noticeably from segment A_1B_1 of the previous phase. The repercussions of this occurrence in sectors, C, D, E and F may be either immediate, or delayed, as in figure b. But sooner or later the distortion of the cobweb will tend to disappear. However, (approximate) symmetry will be re-established only at a substantially higher level of activity, which will then be evidence of strong cumulative expansion.

Let us take a concrete example. Over a thousand articles have already dealt with the various projects for creating legal data banks necessitated by the enormous volumes of documentation to be stored and retrieved. But everything is delayed pending the solution of such complex problems as legal semantics, legal syntax and a thesaurus. As soon as this "breakthrough" takes place, a spate of new applications is bound to occur in various sectors, including, in particular, the creation of a legal information service for the public. information/documentation centres for consumers, centres for political, electoral information, etc.

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1) Grapin, Jacqueline, "L'ordinateur, outil de production", Le Monde, 25 mai 1972.

Diagram 18

BUILT-IN MECHANISM
OF THE GROWTH OF INFORMATION AS A RESOURCE
(COBWEB THEOREM)

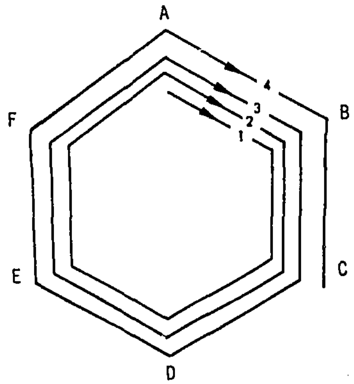

Fig. a

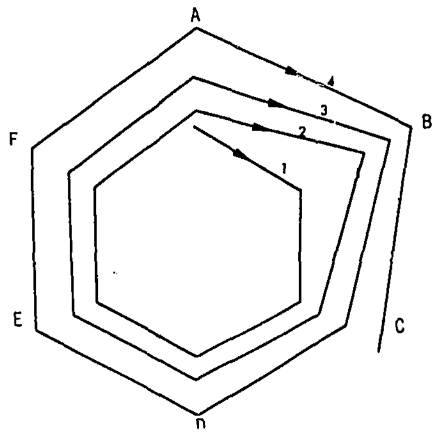

Fig. b

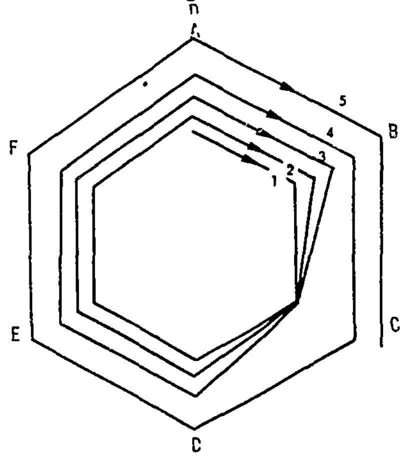

Fig. c

iii) The preceding hypothesis may comprise an interesting variant. Let us suppose that the long-awaited "breakthrough" in sector B is belated. The cobweb will then take the form of figure c in the same diagram. For some time symmetry will be destroyed and the distortion increasingly marked. But once the breakthrough has occurred the period of recovery - or return to normal - will probably be very short.

The cobweb theorem may be transposed to other circumstances, notably multidisciplinary problems. Let us assume that the urban pollution may be measured by means of six parameters(1). When the air in a city is polluted by an especially noxious agent the efforts of research and prevention will necessarily be concentrated on that agent. Once the breakthrough has occurred there will inevitably be a spin-off which will lp to control other pollutants. This brings us back to figure c of the diagram.

Our conclusions, though admitting some nuances may be formulated in fairly definite terms. It is true that no formal proof has been offered of the existence of a central trigger mechanism. The accumulation of "empirical" evidence, however, seems to provide a fairly conclusive proof of its reality and effectiveness.

It is the dual accelerating and autonomous character of the mechanism which must above all hold our attention. Let us imagine that the authorities decide one day to relegate to a secondary plane what was hitherto a priority objective, i.e. the expansion of GNP, in favour of improving the quality of life. Such a political, social and scientific reorientation, far from reducing the overall demand for information, would only augment it.

On the one hand new needs would emerge in areas so far little explored and in multidisciplinary activities. There would also be a strong demand for information from industries forced to accept a certain stagnation or lower growth rate. Their reaction to this slow-down would then be to promote further rationalisation of their activities, which would undoubtedly mean that they would need some knowledge/data/measurements, in other words, information - more precise, more detailed, more carefully elaborated and in greater quantities than before.

1) There is if course nothing to prevent the use of eight parameters, as suggested by Dubon, Roger, "Visualizing the Information for Better Decision-Making" in The Royal Institute of Technology, Stockholm, Sweden, Global and Long-Distance Decision-Making, op. cit., pp. 50-57.

Finally, any change, by modifying a given situation, generates a wave of repercussions and for this reason must be regarded as the source of a new or supplementary stimulus to the growth of information as a resource.

4.7 GENERAL CONCLUSIONS

We now have all the factors needed in order to assess the situation and formulate a certain long-term and even very long-term perspective.

i) Let us begin with an observed fact. The lessons which may be drawn from the morphological analysis of the information/resource do not contradict, but rather supplement and amend, our earlier projections, i.e. those obtained by quantitative extrapolation (Chapter 2) and of scenario writing based on a set of Delphi surveys (Chapter 3).

ii) By thus broadening the base, we were able to provide a reasonably adequate explanation of recent and present trends, including certain aspects which earlier seemed incomprehensible or unclear, such as the continued growth in the volume of information and its sudden acceleration. Then, by taking into account all the quantitative and qualitative forecasts together, we were able to outline the likely pattern of future growth and identify the main tendencies. In the final analysis it is on this set of forecasts that our diagnosis can be based (see the Proposals for action, p. 125.)

iii) There are good grounds for believing that the dynamics or quantitative information growth are largely due to the action of a built-in accelerating mechanism independent of other growth factors. The autonomous nature of this mechanism can best be illustrated by an extreme assumption, so extreme as to border on the absurd. If the number of scientists and technicians, i.e. the principal sources of new information, suddenly ceased growing and their inventive and literary productivity also levelled off, the total volume of information would still increase. This apparent paradox can be easily explained. Beyond a certain threshold of complexity - one which by now has quite certainly been crossed - the slightest change in the existing order of things generates new information needs, requiring in turn at least the synthesis or re-packaging of older information, which will then be circulated in this new form.

iv) Actually, however, this built-in accelerating mechanism acts jointly with many growth factors on both the supply and demand side. If, as certain OECD documents suggest, a global concept of information is adopted, it will assume the character of a resource - a universe comprising a continuum of interlinking and infinitely diversified types of demand and supply. As a whole this information universe expands at a breathtaking rate and certainly outpaces all other contemporary growth phenomena. This is necessarily so, given that information as a resource contributes to these various types of growth, while information as knowledge is sustained by them.

v) In more concrete terms, the upward revision of estimates yielded by our earlier investigations indicates that in 1985-87, six or seven times the present volume of new information will be produced, and that the stock of information-knowledge will be about 120-150 million documents of widely varying types, though predominantly in microform. Generally speaking, therefore, expansion must be expected to continue at an annual rate of 12.5 per cent, allowing for the usual fluctuations.

vi) In 1985 or 1987 the degree of automation of information will approach a hundred times that of today. Automated systems and networks will ensure at least one-fourth and perhaps even one-third of all information transfers. Here growth will therefore be nearly three times as fast, i.e. an average exceeding 30 per cent per year, beginning at a slower rate during the initial seven or eight years and then suddenly accelerating after 1978-1980.

vii) Such a general pattern moreover points to a still greater automation of information activities beyond the 1985 horizon. After 1990, hence within the space of a single generation, automated information will be the rule and traditional information the exception. The revolutionary changes between 1980 and 1990 will therefore be only a prelude to the main spectacle.

viii) At such a scale extremely difficult problems are bound to arise. Yet, contrary to what may be thought, material and financial problems will not figure among the primary preoccupations in 1985 and beyond. Firstly, because the new technology will by then be operational and make the automation of information economically attractive, and ultimately profitable, in many fields. Secondly, capital swallowed up by technological development will have to be offset by orders for new equipment financed jointly from public and private funds. On balance the most serious problems will arise elsewhere.

ix) Since our intellectual capacities are not infinitely receptive, future automated systems and networks will have to be designed and organised in such a way as to supply complete, relevant and noise-free information to every individual or collective user. But no community will ever be wealthy or carefree enough to afford the luxury of reprocessing much the same mass of information thousands or millions of times in order to retrieve a specific item for an individual customer. The reconciliation of these two conflicting requirements poses problem Number one.

x) If the idea of repackaging comes immediately to mind, it should be rejected as a wholly inadequate concept and approach. The solution can only lie in the systematic, continuous and multi-facetted recycling of information. This requires that every simple or complex input be promptly integrated into the existing stock of information according to a likewise multifacetted classification system. The principal efforts of research must thus be oriented in this direction.

xi) This problem, without exaggeration, may be considered a measure of the skills which must be deployed tomorrow by highly qualified specialists, supported by outstanding managers. No university or institute is yet capable of training either group, or of imparting the advanced technical knowledge and keen sense of managerial responsibility which are called for. Here, in fact, is where concerted international action is most urgently needed.

Table 6

	TRADITIONAL APPROACH (Chapter 2)
1. CONTENT OF THE CONCEPT OF INFORMATION	Information = Output and input of R and D Scientific and technical information (STI), exclusively or mainly arising in, and in the service of, the scientific and technological communities
2. ANALYTICAL AND FORECASTING METHODS	Extrapolation of empirically observed trends, with the help of known mathematical models. Refinement of forecasts using a range of trend curves
3. NATURE OF THE ELEMENTS CONSIDERED	Quantitative evaluation of the real or supposed global supply and demand of STI. Cross-check by statistics of scientific population, the main source of the STI and its presumed sole user.
4. CONCLUSIONS AND KEY FORECASTS	The growth of STI will continue at, at least, an exponential rate until 1975, and most probably until 1980-85, because of continued growth in the number of research workers and of their inventive and literary productivity. By 1985 there will be 4 to 7 times as much STI as in 1970, the higher value being most likely and perhaps overtaken if science policy gives priority to social objectives: environment, quality of life, etc.
5. CONFIDENCE LEVEL AND MARGINS OF ERROR	Strong convergence of forecasts whatever models are used, the differences between the strong and weak hypotheses for 1985 being limited to a few years. But all forecasts resulting from extrapolation beyond 1985 should be considered (very) doubtful.

SUMMARY

SOCIO-CULTURAL APPROACH (Chapter 3)	GLOBAL APPROACH (Chapter 4)
Information = knowledge Hence, information transfer = transfer of knowledge in the service of a variety of activities, intellectual and material, together making up the knowledge industry.	Information = basic resource and link between a variety of activities, intellectual and material. Information in the service of all: society, institutions, individuals.
Scenario to 1985 horizon and beyond, clarified and complemented by a presumed correlation between the anticipated growth of the knowledge industries and the secondary growth of the volume of information.	Morphological analysis based on square matrices. Exploration of all combinations capable of orienting research towards optimal or sub-optimal solutions, etc., in terms of systems to be developed, re-organised or constructed from building blocks.
Exploitation of various Delphi studies. Search for confirmatory and complementary opinions. Re-interpretation of the initial scenario in the light of economic constraints, and of unit costs of processing by manual/mechanical/electronic means.	Qualitative evaluation of demand characteristics using the concept of the closed-loop continuum. Assembling intersected continua without predetermined hierarchic order to form a complete spectrum of the information resource.
Favoured by a sustained expansion of the knowledge industries between 1970 and 1985, information needs will grow at least in parallel. But demand will only be satisfied by an increasingly accelerated automation which during this period will increase 100-fold over present systems, especially in priority secteurs: health, education, culture, mass communications, basic and applied research (incl. patents).	The impetus of the growth of the transfer of knowledge seems to be ensured by some independent intrinsic force, which acts synergistically with all other growth factors. In 1985-87 the annual production of new information can be expected to be 6-7 times greater than at present, i.e. a growth of 12.5% p.a. while the progress of automation will proceed initially at less than, then at more than 30% p.a.
These forecasts are based mainly on: extrapolation of technological progress, especially hardware and microform: on the anticipated spectacular reduction of unit processing costs; and on the substantially increased funding which will become available in the public sector by 1985 in priority areas of knowledge.	The existence of this intrinsic force has not been proved, but merely illustrated by a series of real or highly probable situations. Only a computer simulation, starting from the morphological analysis, would enable a determination of the parameters of this mechanism, which seems to gain an added impulse from any exogenous change in the environment.

PROPOSALS FOR ACTION

It is now possible to offer a more general diagnosis and a number of practical recommendations, based on the systematic study of information supply and demand, and on the totality of quantitative projections and qualitative forecasts.

I. GENERAL DIAGNOSIS

i) It is clear that problems related to information transfer have been largely underestimated up till now, in regard to their real magnitude, complexity and growth rates.

ii) The decade 1980-90 will be inevitably a period of revolutionary change, since a host of technological innovations will make desirable and economically feasible the automation of information on a massive scale - probably from 1978.

iii) While it is difficult to evaluate all the consequences resulting from these upheavals, their impact will certainly be felt strongly in the essential fields of education, culture, health, medicine, science in general; this impact will be overwhelming in relation to organisation and management of the public and private sectors.

iv) In these circumstances individuals, institutions and the whole power structure are in the end bound to be profoundly and lastingly affected for better and for worse.

From this stem three requirements:

a) It is necessary to stimulate an awareness of information, and particularly of the only alternatives open to us in the next ten or fifteen years: we must either stifle under an excess of piecemeal, disorganised and "polluting" information - or transform this potential resource into an unprecedented source of material and non-material value.

b) There is an urgent need to bring together all the factors involved here before 1975 in order to define, nationally and internationally, objectives and priorities, and to identify these with adequate means in volume and in quality phased according to a suitable calendar.

c) It is highly desirable that governments and the competent intergovernmental bodies make the necessary decisions without delay in relation to these problems whose solution is at hand.

The recommendations which follow aim to:

i) organise a sufficiently large basis of correct and up-to-date knowledge, beginning with a complete system for retrieving statistics and survey data;

ii) ensure the training of highly qualified management and top-level system designers; and at the same time promote advanced research in the information sciences and technologies;

iii) identify the elements here which will contribute to the formulation of an information policy.

II. INTERNATIONAL MACHINERY FOR MONITORING AND ASSESSMENT

It will be vitally important to ensure that we have some means of monitoring and assessing information developments, including, at the minimum:

i) A statistical system for gathering, organising and analysing data relevant to all information activities: sources, equipment, processes, dissemination, specialised services, automated systems of networks, hardware, personnel, users, etc. A working group of information specialists and statisticians should be given the task of preparing the first international congress on concepts, definitions, procedure and frequency of survey, with a view to an annual publication of international statistics on information.

ii) A tri-annual programme of sample surveys, oriented towards those aspects which normally escape statistical measure, notably: quantitative assessments, semantic analysis, motivational analysis, marketing, etc. In the first place, we have to fill the main gaps as rapidly as possible; for example, by defining and testing evaluation criteria for automated systems or by studying user reactions to automated systems.

iii) The development of planning models should be undertaken without delay by a small team of specialists in technological forecasting and economic forecasting. As more reliable and detailed statistics become available, these models should be improved and augmented by more accurate models. Only by using such models will it be possible to maintain an accurate and up-to-date assessment of future developments.

iv) A Delphi study for OECD Member countries, or at least for the European Members, should be undertaken at an early date to bring together several hundred informed opinions on:

a) future organisational patterns of information services;
b) the optimal structure and configuration of information networks;
c) the foreseeable impact of massive automation of information on individuals and on institutions: governments, administrations, engineering, production, etc. The promotional effect of such a survey provides a supplementary argument in favour of this project.

v) A data bank of forecasts related to information should be set up on the initiative of the OECD. Its tasks would be to bring together, test, validate and constantly bring up-to-date these forecasts. It would prepare, at regular intervals, a "panorama of the future" with five year, ten year, etc. horizons, which would be of great help to those groups concerned (in the public administration, industry and research) who might need to adjust their programmes to suit.

This forecasts bank should result rapidly in considerable savings through the avoidance of wasted effort, overlap and dead ends.

III. INSTITUTE FOR INFORMATION SCIENCE AND TECHNOLOGY

To put an end to the lack of co-ordination and disorder in training and research in information, it is proposed that there should be set up.on the initiative of the OECD,a Higher Institute for Information Sciences and Technology. This should be a flexible organisation of international standing, at post-university level, composed of a small number of permanent professors/research workers able to call on outside expert collaboration and charged with the mission of ensuring:

i) the training of senior managers

a) of networks, sub-networks and major automated information systems;

b) of international, governmental and administrative services concerned with information policy;

c) of the principal industrial firms with activities in the field of information technology.

ii) the training of highly skilled senior systems personnel, with the following specialisations:

a) relations between automated systems and networks and their environment;

b) compatibility and inter-connection of networks, systems and hardware;

c) a continuous re-cycling of information (see below):

d) an understanding of the organic links and interchange among data banks and uni- or multidisciplinary analysis centres:

e) an understanding and practical operation of interchange between systems and networks in the private and public sectors, including information for private individuals.

iii) the advanced training of teachers, that is to say of the professors who have the heavy task of ensuring, at the national level, the teaching of information sciences and techniques which are complex disciplines, with ill-defined frontiers, often lacking the necessary theoretical bases.

iv) fundamental research, whose main guideline should be the continuous re-cycling of information, resulting from the need to replace the out-dated and cumbersome principle of a single processing by that of the rational re-utilisation of all available information. The object here is the continuous production of new information, integrated, synthesised or broken down according to a continuous spectrum of needs.

v) the expansion and development of information sciences, by making available for all concerned:
   a) a world-wide library and documents centre;
   b) a "referral centre";
   c) facilities for consultation or for international meetings;
   d) a fund for financing publications ensuring the world-wide dissemination of works of major importance.

IV. TOWARDS AN INFORMATION POLICY

The definition - by OECD and by governments - of an information policy worthy of the name, will remain a pious hope as long as a preliminary agreement has not been reached on the means of formulating it, on a target date which should be 1975, and on intermediate steps. At the conclusion of his study, the author believes it is his duty to put forward some suggestions:

i) The choice between basic options. OECD should adopt immediately a position on a number of preliminary issues, which may influence future progress:

   a) Should information problems continue to be treated in the narrow perspective of science and technology, and left to scientists and experts alone? Or should they be envisaged in the broader context of knowledge and social welfare? Or even approached along the lines of development of information as a fundamental resource?
   b) Can governments allow automated systems and networks to develop in a chaotic fashion and for strictly commercial motives? Can they give up all control over the new technologies which will come into use everywhere during the next ten years?

c) Should the OECD attempt to exert a moral influence and try to identify the main development paths for information in line with the political and social objectives of Member countries?

ii) A survey among Member governments of the OECD should be undertaken and completed within a year(1). This survey has a vital importance and should be carried out under conditions ensuring its success. It should seek to identify:

a) not only official viewpoints but also personal opinions (whether orthodox or not) of those responsible in this field at the national level; it will therefore be necessary to use not only a questionnaire approach but also the technique of personal and confidential interviews;

b) the proposed survey should aim, among other targets, at bringing out the extent to which the role of the information resource is accepted in pursuit of policital, economic and especially social objectives;

c) rather than bringing back only data about current information policies, it will be more important to discuss policies currently under development, so that an assessment will be possible of what the governments are planning in the fairly near future.

iii) An international information charter will be sooner or later indispensable and it will therefore be of great policy value to begin preparing it, at the level of OECD, in defining and codifying

a) the right of access of individuals or public or private bodies to this information resource and the inherent limits to this right;

b) the political and social guarantees which individuals and institutions can legitimately expect, including protection of privacy and professional secrecy;

c) the basic rules of reciprocity which should govern relationships between public and private systems and networks;

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1) As already suggested by the U.S. Delegation to OECD.

d) a code of ethics for professions and industries concerned in this field.

iv) <u>An organisation for technical co-ordination</u>, distinct from the OECD, should be introduced as soon as possible with the assistance of industry to:

a) promote the introduction of compatible and/or complementary technologies;

b) harmonize research programmes and production schedules of manufacturers of hardware concerned with informatics, telecommunications and peripheral equipment (without weakening the spirit of free competition);

c) facilitate the introduction of micro-reproduction into the traditional mass communications media.

v) <u>The foreseeable transfer of manpower</u> from primary and secondary activities towards information activities could help in solving the problem of technological unemployment which will become serious towards 1980. A co-ordinating group of experts in manpower and information sciences should be given the task of:

a) complementing present estimates for future manpower needs and availability;

b) formulating a re-training programme for the some millions of individuals who will be changing jobs; finally

c) proposing the creation of competent bodies to resolve these problems without excessive social shock.

The variety of proposals put forward here may seem too far-reaching. They do, in fact, present a variety, which mirrors the variety and complexity of the problems to be attacked. They have, however, a common denominator since they are aiming at a single objective: to master the power of information, to avoid submitting passively to disorganised development and to withstand its adverse side effects.

As for being too far-reaching, this is the prerogative of resolute men who have a clear vision of what lies in the general interest and within the obligations which are laid on them personally by reason of their high responsibilities in the OECD or elsewhere.

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