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Trends in technology forecasting

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Abstract: The current state of the art of technology forecasting (TF) is critically reviewed. A statement of the aims of TF, which distinguish it from futurology, a brief history and a summary of the basic principles are provided. The last includes the technological escalation, technological succession, societal impact and methods of quantification. TF techniques are divided into two pairs of classes: extrapolative versus normative and single-variable versus multivariable. Each is critically evaluated in terms of its potential applicability and reliability. Substitution analysis, Delphi techniques, cross impact analysis and morphological analysis are treated in some detail.

It is concluded that some form of TF is essential to the success of strategic planning and its use will undoubtedly increase in the future.

Technology forecasting is moving from single-variable approaches to multi-variable analysis, the latter often including social, economic and environmental trends. This paper discusses the current objectives of technology forecasting, the state-of-the-art and some trends in its methodology and its applications.

Technology forecasting studies are systematic investigations into the future development and application of technologies. It is not so much that one wants to predict the future but rather one wants to see:

—which interactions exist with other developments;
—which actions are possible and what effects they will have.

Developments rarely come alone; accompanying developments further or retard change. When a number of mutual cause and effect relationships can be demonstrated, one can speak of a complex development. Complex developments make the future less predictable than simple developments. Inspection of possible future developments, laying bare the pattern of cause and effect relationships and consideration of the actions that can be taken and their results, are the aims of technology forecasts.

Technological developments apart from being dependent on other technological changes are increasingly influenced by economic, social and political developments. The opposite is also true. This has led to the fading away of the borderline between technology forecasting and futures research. This is helped by the fact that both fields of study use more or less the same methods. Nowadays, the term technology forecasting applies more to the object of study than to the method.

The results of technology forecasting studies can be used as information for policy formulation and opinion-forming by organisations and individuals. In companies and other organisations technology forecasting is part of the process of strategic planning.

Technology forecasting is therefore usually carried out pragmatically. The studies have a relatively short time horizon of 5–10 years and are limited in the scope of the object of study.

In this sense technology forecasting differs from what is usually referred to as futurology. The latter is a philosophical consideration of the future with time horizon and scope usually wider than those in technology forecasting, and where the personal opinion of the futurologist is paramount. Some futurologists have developed a logical and sound system of reasoning very often close to philosophy. These visions can be very penetrating and stimulating. The object of these futurologists coincides with that of the philosophers: they wish to make societal developments more transparent and accessible by describing them in a usually unorthodox way. Often there are secondary objects such as the warning of undesirable developments or the description of possible developments towards a desirable future. Futurology studies can be unusually interesting though one has to separate the chaff from the wheat, but for policy formulation in companies and organisations they are of lesser interest. This is because there is little correspondence with the concrete policy decisions the company or organisation must make in view of the future.

Technology forecasting was developed first at the end of the Fifties in the U.S.A. and for two reasons. First, there was an effort to apply new technological principles as soon as possible on as broad a scale as possible.

That meant searching for new fields of application, influenced by the high development costs of new technological principles. The second reason can be found in the great technological projects being developed at that time in the U.S.A., especially the space projects. The so-called parallelization of development work was used on a large scale in these projects. This means that components of a large transport aircraft for instance were not developed one by one but were developed in parallel on the basis of fairly strict specifications. Such specifications covered completion date, quality and costs as well as the structural design of the components. Such parallelization is possible only when one can make a reasonably reliable estimate of the time to completion of the various projects. In order to make such estimates technology forecasting was developed as a technique.

Technology forecasting was initiated in the U.S. public sector in order to be able to manage increasingly complex technological developments. In the private sector it emerged in the same period as strategic planning.

Technology forecasting is based on a number of general experiences with developments of technologies; on the basis of these experiences a number of techniques have been developed. Technology forecasting does not follow a fixed methodological pattern however and the way in which the study is approached and the choice of methods depends on the individual researcher.

In the following sections we shall go somewhat deeper into the experiences on which technology forecasting is based and into the methods. In later sections we shall discuss current trends in technology forecasting, followed by an evaluation of the technique.

GENERAL PRINCIPLES OF FUTURES RESEARCH

Generally speaking, futures research is possible only because many of the circumstances that will shape the future have already materialised. Processes of change within an individual or within a society usually are slow. The reader will notice however that many changes seem to occur very suddenly: the eruption of a vulcano, a sudden revolution in a far-away-country, a new pop group becoming the rage. A close analysis of such events teaches us however, that the limitations of our perception and lack of understanding of interactions make the event look sudden.

For someone who was aware of the details of the social and political developments in the country, the revolution would not have been at all sudden. If we had known exactly what was going on inside the earth, the volcanic eruption would not have come as a surprise.

Processes of change are in principle slow. We can add to this by saying that every process has a beginning and an end. This seems a somewhat trivial remark but one can study the conditions under which a development will take off and those under which it will reach its culmination. During its development any trend will be influenced by other trends and vice versa. If these influences act simultaneously, the trends can amplify or attenuate each other.

When the trends are not simultaneous, cyclical patterns such as economic cycles may occur if the termination of one trend is a condition or the initiation of another and vice versa.

These mutual interactions severely complicate futures research and so does the fact that many tendencies can only be observed in an aggregated form. The voting behaviour of an electorate for instance is composed of thousands of underlying tendencies. These two mechanisms prevent certain trends from being measured and always render the picture of cause-and-effect relationships incomplete.

BASIC PRINCIPLES OF TECHNOLOGY FORECASTING

As already stated technology forecasting is based on a number of observations or reasonings connected with technological developments. The first observation I would like to mention is that of *technological escalation*. When the performance of various material embodiments of a technology is plotted against time, a surprisingly regular pattern often appears. An example, given in Figure 1, is that of the electric bulb. The quality is here expressed as light units (lumens) per unit of energy (Watts). It is seen that the curve is S-shaped, a form frequently found. This can be interpreted as follows. The development of the new technology gets under way as soon as a number of bottlenecks are removed. Due to learning effects, the quality grows initially exponentially. Every technology has, however, its performance-ceiling; this ceiling is approached with a reverse exponential curve. Combining the two, the characteristic S-curve emerges.

The second experience is that of *technological succession*. It often appears that when a technology has reached its ceiling, a new technology is developed with a higher ceiling. The development of this second technology also follows an S-curve. This too is shown in Figure 1.

In Figure 1 the two curves do not cross, but in practice they often do, as indicated in Figure 2. Technology I saturates at t_4. At the moment t_2, the first signals of technology II become

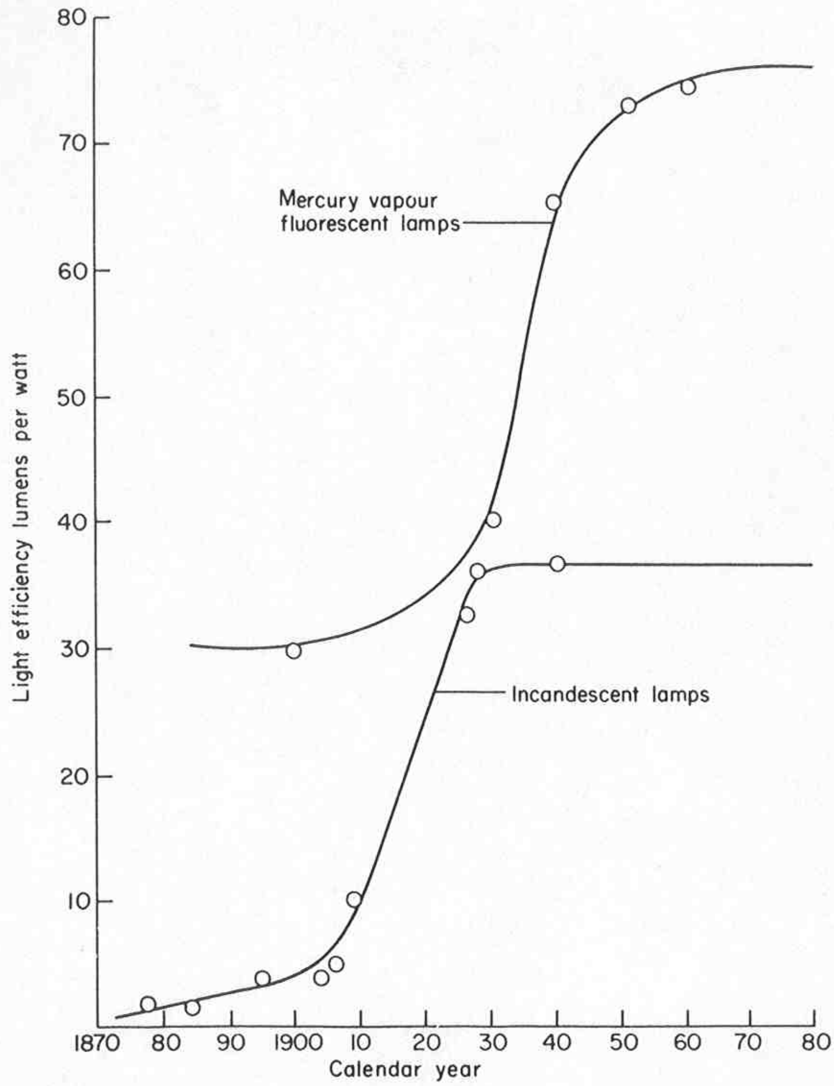

Figure 1. An example of two technological escalations: the light efficiency of incandescent lamps and mercury lamps against time.

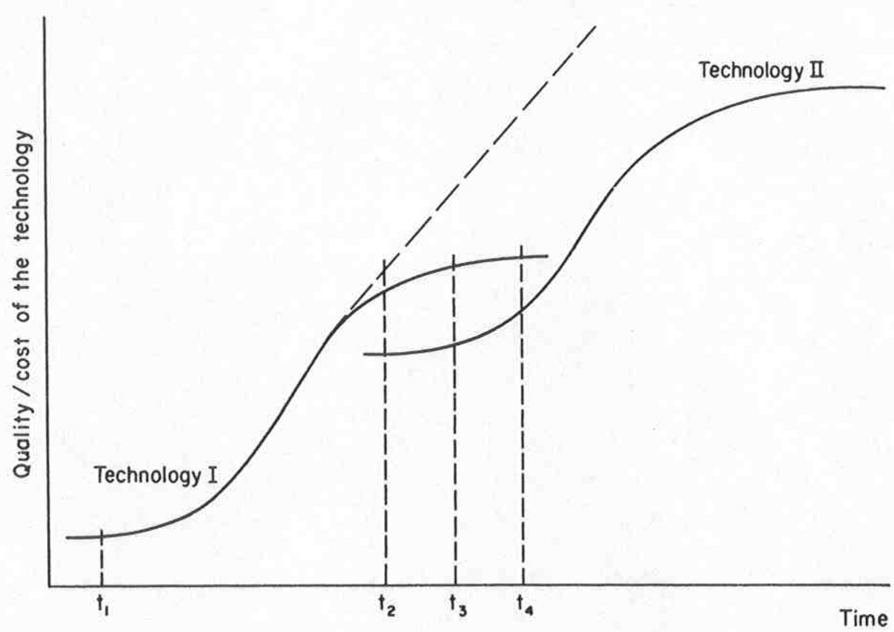

Figure 2. The mechanism causing an underestimation of the potential of new technologies.

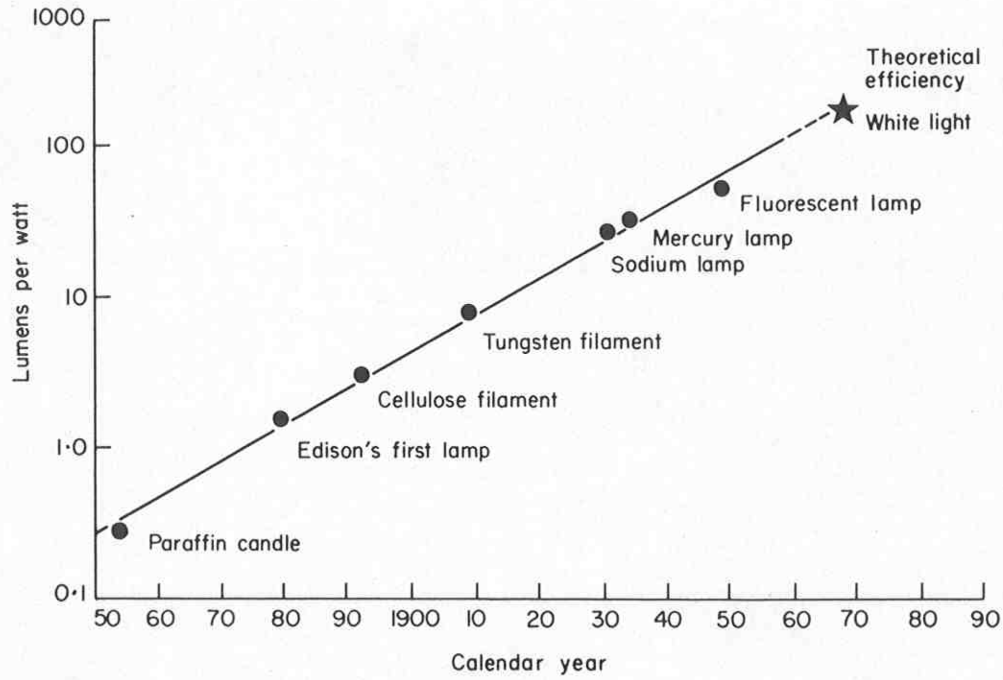

Figure 3. Technological succession.

apparent. Between t_2 and t_4 there is a transition period. It will be shown later that the development of technology II was regular from t_3 onwards. However, at this moment the policy makers, ignoring the fact that every development has a ceiling, will think that technology I will develop according to the dotted line ("hockey stick" forecasting). Therefore, they are likely to underestimate the potential of technology II, saying that both its performance and its rate of performance improvement are inferior to those of technology I. This mechanism is perhaps the most serious cause of company bankruptcies.

Figure 3 illustrates technological succession by plotting against time the points at which a number of illumination technologies reached their maximum performance. It also shows the maximum performance attainable. That is the point where all the energy is converted into light. Unfortunately it is not always possible to show this maximum point absolutely.

A third observation is the connection of technological developments with, for instance, developments in society. An example of this is the uncertainty regarding the future use of buildings and houses. In the past very little consideration was given to possible evolutions in the desired uses of houses, so that we now have a stock of houses which for instance cannot easily be converted into houses for single persons. To-day this is considered a serious shortcoming and in such a situation one can expect the development of technologies providing a more flexible use of houses and buildings.

And in fact this is the case if one thinks of the development of structure-finishings specialization and on a wider scale developments of systems such as modular coordination which make open system building possible. While one naturally cannot forecast which new technologies will arise from the needs of society, it is possible to indicate that certain sorts of developments will take place.

Technological developments often cast their shadows a long time before they appear. The first publications on the possible development of prestressed concrete date from 1896. The first patent was granted in 1928. The first manual on prestressed concrete appeared in 1936. Even so, this technology was widely applied only after the second World War.

Often, not only in scientific journals and patent abstracts but also in totally different sources, one can identify what new technologies are in a test stage and by whom they are being developed. This information can be of inestimable value for the company.

A fifth observation concerns the development pattern of a new technology. This pattern usually shows a surprisingly regular behaviour with clearly identifiable stages. The first stage has to do with the scientific discovery or the discovery of a certain market need. During the second stage a theory is formed or a model made of the technology required to satisfy the market need.

In the third stage the theory is tested at laboratory level or a test model is checked. During the fourth stage the scale is increased to encompass a test project or test factory after which market introduction follows as a fifth stage. The sixth stage is the general use of the new technology and further rationalization.

A seventh stage is sometimes considered as the spreading of the technological principle to other fields of application, but this extension can also occur during the other stages. An outline such as this has already been suggested by Bright (Figure 4). When a technology has

STAGE	IDENTIFIED BY
1	SCIENTIFIC SUGGESTION, DISCOVERY, RECOGNITION OR NEED OR OPPORTUNITY
2	PROPOSAL OR THEORY OR DESIGN CONCEPT
3	LABORATORY VERIFICATION OF THEORY OR DESIGN CONCEPT
4	LABORATORY DEMONSTRATION OF APPLICATION
5	FULL SCALE OR FIELD TRIAL
6	COMMERCIAL INTRODUCTION OR FIRST OPERATIONAL USE
7	WIDESPREAD ADOPTION AS INDICATED BY SUBSTANTIAL PROFITS, COMMON USAGE, AND SIGNIFICANT IMPACT
8	PROLIFERATION

Figure 4. Stages in the process of technological innovation according to J. R. Bright.

passed through a number of stages it is as a rule possible for experts to make a relatively realistic estimate of the further pattern of behaviour in time of the remaining stages.

Lastly we might give as an observation the fact that many technological parameters can be expressed in figures so that they can easily be set out graphically. In this sense social forecasting is more difficult than technology forecasting with economic forecasting lying between.

	EXTRAPOLATIVE (TRENDS)	NORMATIVE (POSSIBILITIES)
SINGLE VARIABLE	DELPHI TREND EXTRAPOLATION SUBSTITUTION ANALYSIS SPECTRAL ANALYSIS	X
MULTI VARIABLE	CROSS-IMPACT ANALYSIS SYSTEM DYNAMICS SCENARIO	MORPHOLOGICAL ANALYSIS MONITORING RELEVANCE TREES

Figure 5. Methods of technology forecasting.

What are the methods developed on the basis of the observations named? They can be divided in two ways. Firstly we can distinguish methods making it possible to extend historical trends—the so-called extrapolation methods—from normative methods that investigate what the possibilities of the technology or the development are in principle. Another division is according to methods directed towards one variable as against multi-variable methods. When we combine these two divisions we get Figure 5 where a number of methods are named. We will now discuss some of these methods.

MONOVARIABLE EXTRAPOLATION TECHNIQUES

We will consider trend-extrapolation, substitution-analysis and the delphi method.

In trend extrapolation a characteristic parameter is plotted against time. The parameter can be a quality criterion or a cost value. Sometimes mixed parameters are used. For aircraft for instance both the speed and the payload are important. These are combined by plotting passenger-kilometres per hour against time.

The characteristic parameters often increase or decrease exponentially. Such functions can be made straight by using semi-logarithmic scales.

One must be very careful in extrapolating trends. In the introduction we stated that exponential growth never continues unrestrictedly, and that dampening begins after a certain level of saturation. In the case of technologies that are essentially new in the sense that they do not wholly or partially substitute an older technology, it is often difficult to determine this level of saturation and therefore the flattening-out of the S-growth development curve. This means that trend extrapolation can only be used during the central trajectory of the S-growth curve.

In other words, the following two conditions must be fulfilled:

—the ceiling must certainly not yet be in sight;
—the forces that shaped growth in the past must continue unchanged in the future.

If the latter is not the case, there is the question of discontinuity and it is senseless to extrapolate the past. Unfortunately, both conditions are often violated in practice, meaning that forecasters use semi-log extrapolation when it is untenable. This is because this kind of extrapolation is easy and because the expectations of technologists about their technologies are often much too optimistic. They are often reluctant to accept that every development has a ceiling and that developments can be retarded by social or economic developments or situations.

It is curious that extrapolations are almost totally limited to the time domain although powerful techniques are available for analysis and extrapolation of data when transferred to the frequency domain. These techniques are known as spectral analysis.

Using the Fourier transformation, a time series of numbers—for instance, sales figures—can be transformed to the frequency domain. This gives a plot of the density of the signal against frequency. Cyclical elements of the time signal now show up as peaks in the frequency signal. An extrapolation can be made in the frequency domain and the results transformed to the time domain. This type of analysis has been applied very successfully in the textile cycle (about 3 years), the normal business cycle and longer economic cycles such as the Kondratieff cycle.

Examples of the use of spectral analysis in technology forecasting are unknown to the author.

Substitution analysis is a technique used to follow and investigate the extent to which a new technology substitutes an old one. In this case a lot more is known about the definitive ceiling; often there is the question of complete substitution. The uncertainty with substitution-analysis is mainly the question of whether the new technology will really supersede the old one or whether the new technology will stimulate the old one so that it remains in control and stops the new one developing further. However, if one has arrived at the point when it can with great certainty be said that the new technology will completely replace the old one, then substitution analysis is a very powerful technique and the results can be forecast reasonably well.

The simple formula of Fisher-Pry is often used in substitution analysis:

$$\frac{df}{dt} = \alpha f(1\text{-}f)$$

Here f is the degree of substitution, t is time and α a constant indicating the slope of the substitution curve. As can be seen, the speed of substitution is proportional to the amount of substitution and also the amount yet to be substituted. This has to do with the fact that people go over to the new more quickly if others have done so before them and on the other hand with the fact that growth is proportional to market power. If we integrate the above formula we get:

$$\frac{f}{1\text{-}f} = \exp\ \alpha(t\text{-}t_0)$$

This means that if we plot f/1-f against time on a semi-logarithmic scale we get a straight line.

Many substitution analyses have been carried out in the past. Figure 6 shows an example of the substitution of sailing ships by steamships. The full-line curve shows the actual history while the dashed lines give the substitution patterns

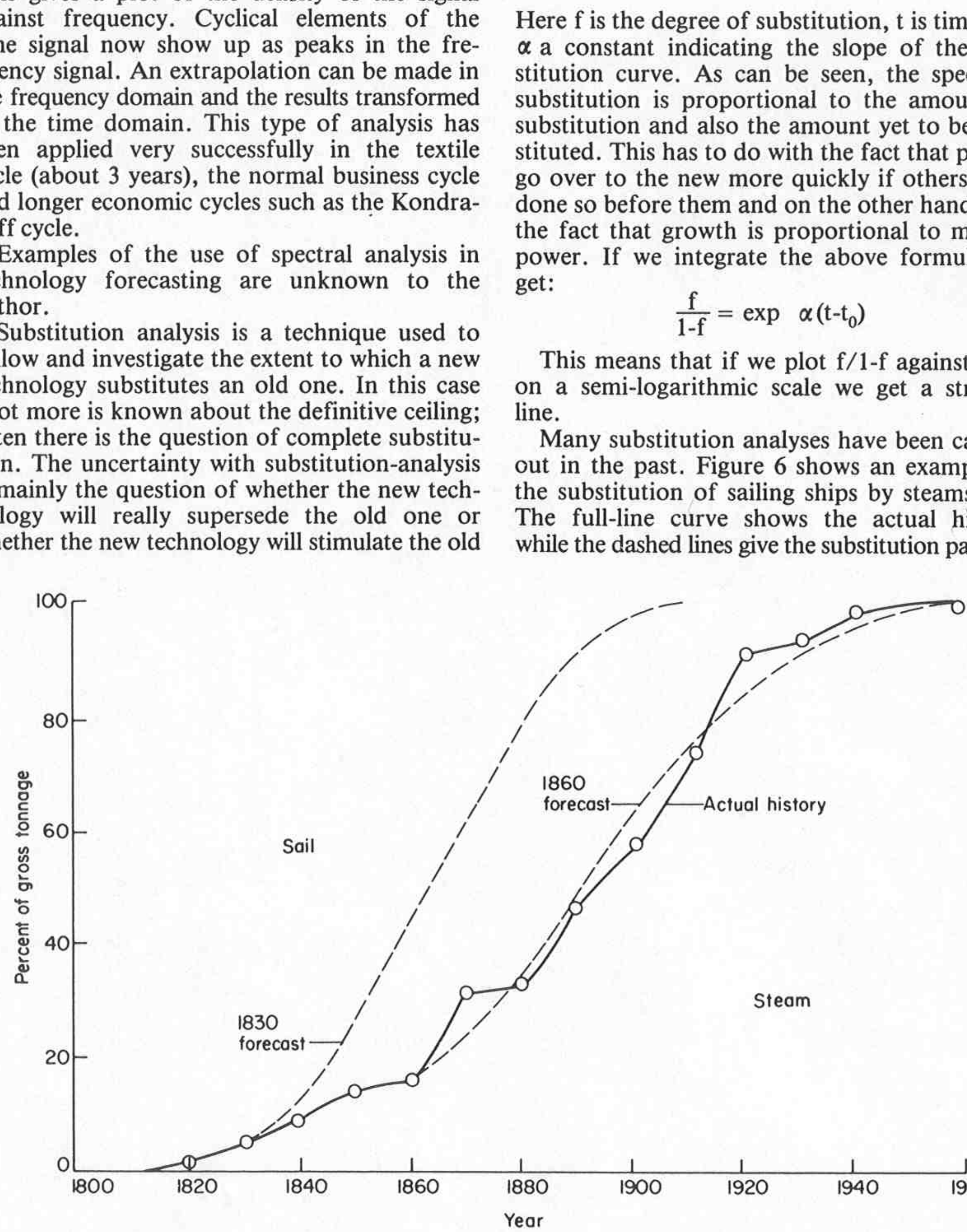

Figure 6. Substitution of steam for sail—1830 forecast, 1860 forecast, and actual history.

that could have been calculated in 1830 and 1860. It can be seen that the forecast of 1830 is too optimistic; in other words, that substitution progressed more slowly than could then be expected. We imagine that the reason for this lies in the fact that the old technology fought back as it were, which meant in this case that the sailing technology was raised to a maximum by building the sailing clipper. This effect could be included in the forecast of 1860 which is the reason this forecast covers reality quite closely from that time onwards.

Lastly, in the delphi technique, a number of experts on the technology under investigation, are asked when they expect a certain important breakthrough to occur.

In a delphi study the participants answer the questions more than once. For the second round of questions the first answers and the main arguments from the group are fed back. The participants are again asked to answer the questions in the light of the first answers with arguments. Some participants will change their opinion, others will not. The group answer for the second round will thus be different from that of the first round; often the answers grow towards each other if the participants are open to the arguments of each other. When the consensus within the answers is sufficiently clear or when the answers remain far apart the study is terminated.

The delphi method has been developed in order to make discussion between experts possible without permitting a certain social interactive behaviour as happens during a normal group discussion and hampers opinion forming. During a group discussion one generally listens more to participants who have built up a certain authority than to other participants so that important information is not given sufficient prominence.

Evaluating the delphi method we can say that it is very laborious and cumbersome, especially as some believe the results could also be reached through direct interviews. On the contrary, the advocates of the delphi method respond that interviewers are seldom completely objective and that this effect is avoided by the delphi method. We believe, however, that a responsible interviewing technique, such as when two interviewers do the interrogation, need not be more subjective than a delphi study and this method is certainly much more effective in terms of information received per unit of time. At the moment we see that many futures researchers have set the delphi method aside. Market researchers in contrast are using it more and more. Unfortunately the term delphi method is also sometimes used for a normal inquiry among a number of experts.

We include the delphi method under extrapolation techniques because the participants reason mainly with the past in mind and tend to extend developments from the past into the future. Moreover, the delphi method is one-dimensional since every development is looked at separately; interaction with other developments is not systematically investigated.

MULTIVARIABLE EXTRAPOLATION TECHNIQUES

In reaction to the monovariable techniques for technology forecasting multivariable techniques have been developed. These techniques try systematically to see which developments interact with the development being studied. Some developments will further the development being studied while others will work against it or even obstruct it. Because of the many connected influences and their different nature, the development of the one variable is very complicated. For instance, development A can have direct positive influence on B but A can simultaneously positively influence C which, however, has a negative influence on B. While one would expect the development of B to be stimulated when A takes place, the opposite can be true. If it happens that the development of B is strongly stimulated or retarded by 20 other developments besides A and C, and that these 20 influence each other mutually, then it is difficult to determine how B will develop in connection with our expectations for all the other developments together.

The more important techniques by which such a network of cause and effect relations can be tackled are cross-impact analysis, mathematical models and scenario techniques.

In cross-impact analysis the more important developments within the framework of the developments under study are summarized. These trends are described in such a way that the value of the trend can be stated, for example, for the years 1980 and 1990. Once the trends have been determined, a team of experts can be asked to estimate their values for 1980 and 1990. We call these the 1980 values and the 1990 estimates.

The team then determines the weighting of interactions between the various trends. This is done by asking whether trend j will be stimulated or retarded when trend i occurs. The measure of interaction is indicated for example with a figure between +5 and −5. Instead of these figures descriptive weights can be given such as: very strong positive interaction, weak positive interaction, no interaction, weak negative interaction, etc. The estimation of the interactions in itself requires a quite extensive effort.

If one is studying 20 trends then there are 380 interactions. Small differences between experts are averaged, large ones thrashed out in a plenary meeting.

When the estimates for the interaction coefficients and for the initial and final values are ready, the computer is used to calculate the set of so-called calculated final values. The idea behind this is as follows. Anyone with a perfectly functioning brain would estimate the final values such that consideration is taken of the interaction with other developments both as regards the strength of interaction and the strength of the driving force of the developments as expressed by the difference between estimated initial and final values. For a normal person it is practically impossible to take account of a somewhat complicated set of interacting developments in such a way that the estimated final values be consistent with the values of the interaction coefficients and those of the driving forces of the various developments. In other words, there will always be discrepancies between the estimated final values and the calculated ones.

One opinion is that a certain development will progress strongly and this is expressed by setting down a high final value for this development. At the same time many retarding effects on this development can be perceived, which find expression in a number of negative interaction coefficients. When we go on and calculate we find that the calculated final value is far below the estimated final value. In that case the user can do one of two things.

He can admit that his estimated final value was too optimistic and adjust the value, or he can maintain that his final value was realistic and that he over-estimated the negative interactions. He can make adjustments in the final values or interaction coefficients or both and run the calculation again. By doing this repeatedly until the calculated and estimated final values approach each other the user learns what the inconsistencies in his thinking were.

Once we have a consistent set of interaction-coefficients and final values, the model can be used to estimate the effects of certain events. By this is meant events that influence the whole set of developments but are not themselves influenced by the set of developments. For example, a second energy crisis would influence a number of developments in the construction sector but the occurrence of such an energy crisis is independent of the situation in that sector of industry. In the same way the influence of government measures can be studied. Instead of guessing whether a certain government measure will be taken or not, two calculations are carried out, one with the government measure, the other without. Comparison of the two calculations shows the effect of the measure. In this last case especially, cross-impact analysis is very powerful.

From the above it is clear that a cross-impact investigation is not easy to carry out. In the first place one has to have a computer program. Some American and recently some British research institutions have programmes available. However, much time goes into the preparation and training of the group of experts. On the other hand we have the advantage that the results of the cross-impact analysis are much more valuable than those of single trend extrapolations.

We can be shorter on a second method of multivariable futures research. Various sorts of mathematical models can be constructed for the various developments and their interactions. A well-known type is System Dynamics, especially in prominence since the studies of the Club of Rome. Other forms of mathematical models are the business and financial models for companies. These models consist in fact of a simplification of a set of non-linear differential equations.

A third method for multivariable futures research is the method using scenarios. Scenarios are descriptions of a possible future where the various parts of the description are connected with or flow logically from one another. They are usually slightly schematic, archetypal descriptions, intended to make clear to the reader and researcher what the consequences of certain situations and actions are. Scenarios should be constructed departing from a common model. In this way the mutual relationships between scenarios can be seen. A chemical company for instance can construct a scenario for the eventuality of its going strongly international or for the case it does not. In both cases the scenario gives a description of what the company will probably look like after five years.

The advantage of using a number of scenarios is that "the" forecast of the future does not have to be made. Especially in the case of general developments this is rather difficult, as there is a tendency to take what is wished as that which is most probable. This is avoided in this method since wishes are expressed in the form of a preference for a particular scenario while the developments within a scenario can in principle be traced more objectively.

NORMATIVE METHODS

A third group of methods we will look at are the so-called normative methods. Even if these methods have been used relatively little, they can be quite important in finding innovation and diversification objects. Normative methods use not so much developments as they have occurred in the past, but rather are directed towards what can be imagined as possibilities in

DIMENSION			SHAPE			
Separation between	solid-solid	solid-liquid	solid-gas	liquid-liquid	liquid-gas	gas-gas
Surrounding one phase	totally	partially				
Barrier against	gravity	mechanical forces	heat	radiation	sound	
Combined with	paper	plastic	wood	paint	none	

Figure 7. A morphological box for cardboard.

the future. When one has inventoried these possibilities, then an investigation is usually carried out of their feasibility and attractiveness in practice.

One method of this sort is the so-called morphological analysis. In morphological analysis first a number of dimensions of technology are set out. By this is meant a number of fundamental characteristics that can be used in different ways. An example from the reference cited is given in Figure 7. This morphological box as it is called has been constructed for the material cardboard. One of the dimensions can be seen to be derived from the fact that cardboard can resist certain forces. If we use cardboard as a means of packing then it is a means of resisting the forces of gravity (e.g. a box of sugar; without the box the material would fall all over the table) or resisting external forces such as mechanical mishandling during transport and transshipment. The core of morphological analysis is that this characteristic, resistance to forces, is applied generally by asking oneself what other forces a piece of cardboard can resist or protect against. Then one sums up all the forces one can think of without asking if cardboard is so suitable for them. These factors are those of radiation, heat, sound etc. After one has set down similar so-called realization possibilities for the other dimensions, combinations of these realization possibilities are set down. This leads to a great number of combinations for each of which a form of realization is sought. In this way new products can be discovered such as the use of cardboard as a heat insulator, cardboard as sound insulating wallpaper, cardboard in doors, etc.

A lot depends in morphological analysis on the creativity of the team of investigators and also the leader of the group who must seek an optimum between an interesting and creative meeting and a systematic search for new possibilities.

The use of morphological analysis does not have to be limited to certain technologies or materials present at a point in time. It can also be used to investigate what products could possibly fulfill a given function. Completely different products can fulfill the same function, think for instance about the various materials that perform the stress-bearing function in buildings. Besides competition between similar *products* such as those produced by different suppliers of prestressed concrete, there is competition between different *systems* such as that between steel-framed structures and concrete for stress-bearing. The competition between functions is often more unexpected and therefore more dangerous than competition in the products field which is more easily kept in view.

In some cases the scenario technique can also be used as an instrument for normative analysis. Instead of starting the investigation with the present situation one begins in the future for instance with the 'fact' that in 1995 an artificial island in the North Sea is put into use. Then one works back and analyses in which year construction must begin, which technologies are used, what kind of organisation is necessary, which permits are required and what social climate is required for the issuing of such permits. Perhaps one comes to the conclusion that it is totally impossible to have such an artificial island ready in that year. In any case an analysis like this helps to identify a number of critical decision points in the process.

Techniques for normative analysis are used relatively little. The methods are as yet underdeveloped perhaps because of the fact that business science directs itself generally to the development of techniques aimed at answering specific questions instead of techniques aimed at raising new questions.

EVALUATION

Single-variable extrapolation techniques are by far the most used in technology forecasting. At the same time they have the greatest limitations. Trend extrapolation is only meaningful over a limited trajectory in time and under specific circumstances. Substitution analysis is among the more powerful methods of technology forecasting, but it is also only applicable in certain circumstances. The delphi-method can bring many new viewpoints, but requires a very thorough preparation for the questionnaire and is quite limited as regards the number of questions. Moreover. there is no control whatsoever over the care taken by the participants in answering the questions.

Multivariable techniques for technology forecasting or futures research demand more time and knowledge than the monovariable techniques. On the other hand the results are more integral and therefore have more value when determining policy in companies and organisations.

The normative methods can be of help when systematically searching for new application areas of a technology or for technologies that can satisfy a given market function.

What is the usefulness of all these techniques of technology forecasting? For companies and institutions that mostly improvise in their work and do not work on the basis of some sort of systematic strategic planning the usefulness is very doubtful. If one carries out a technology forecast, the chances are that a good idea will emerge, but that is as far as it goes.

Companies using a systematic procedure for strategic planning can benefit much more from technology forecasting, because this makes the external analysis or environmental investigation phase much more penetrating. The quality of decisions is on the average proportional to the quality of the information on which they are based. Increasing competition and complexity of the company's environment forces them to formulate policy more explicitly and technology forecasting can assist by providing a basis for these policy decisions.

The use of technology forecasting in innovation processes can be expected to increase in the future even if we must warn against excessive expectations.

Technology forecasting is no panacea for the uncertainty in developments in the environment of companies and institutions, and it does not give immediate solutions to a given problem. It can, however, map out the problem field systematically, help to reduce the surprises in developments and help in analysing the effects of possible decisions.

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