



Technological Forecasting

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Technological Forecasting

Technological Forecasting (TF) is concerned with the investigation of new trends, radically new technologies, and new forces which could arise from the interplay of factors such as new public concerns, national policies and scientific discoveries. Many of these forces are beyond the control, influence and knowledge of individual companies.

Technology Foresight is a combination of creative thinking, expert views and alternative scenarios to make a contribution to strategic planning.

The future is almost by definition unknown, but in both forecasting and foresight activities the judgements or opinions of experts are used. Experts can be used singly, or in numbers. Different techniques can be applied to provide either a consensus view, a range of opinions, or maverick views. The kinds of exercises that can be carried out vary enormously in their complexity and structure and in the ease with which they can be managed.

The simple expedient of subscribing to a technical journal, or belonging to a network or collaborative R&D project, or finding out what research is being done by a relevant research organisation, can all be the first stage towards setting up a more structured approach.

Planning the exercise and getting started

When planning to start either forecasting or foresighting it is useful to consider:

- The reasons for doing it.
- What resources will be needed and what resources can be made available.
- How long will it take?.
- How to learn the techniques and improve the overall process?

Establish the need

In order to assess if a more systematic approach will be useful the following factors can be considered:

- The criticality of technologies used by the company.
- The maturity and rate of change of critical technologies.
- The nature of the R&D strategy, (eg whether offensive or defensive).
- The complexity and flexibility of markets and the overall business environment.
- The magnitude and direction of technological progress in general is driven by financial investment and by market forces and needs; these must also be watched and monitored as part of any forecasting activity.

Co-ordinating resources

Decisions must be made about who should manage the forecasting process. It is not a task for a junior member of staff. It may need a multidisciplinary team or a single individual with adequate authority to co-ordinate across several departments. In all cases the exercise should first seek to use the knowledge and expertise of individuals within the company. Their specific knowledge of company activities and processes will be useful; much additional information can also be gleaned from their contacts and networks and from their appreciation of the general business environment.

Establish and improve the process: forecasting

The process has two primary activities: information [gathering](#) and [analysis](#). The value of the overall process to each company depends on how the two main activities are carried out, how the techniques are customised, and the extent to which the process is followed through to recommendations and actions. They are often applied in iterative or parallel processes. It is not necessary to complete the whole process to appreciate the potential benefits so the process reinforces itself and encourages further iterations.

Activity 1: collection of relevant information

The major issues to be addressed are:

- What information and what kind of data are relevant?
- What sources of information are to be used?
- How accurate is it?
- What systems need to be set up to provide information and data on technological developments and trends?

Practical decisions arising from consideration of these issues include:

- Which journals to monitor, and how.
- Which conferences and trade fairs to attend.
- How to share information.
- Who should participate in which networks.
- How can an individual's relevant expertise best be used?
- What internal data to collect and external data to acquire.
- How to track performance parameters of competitors' products?

Activity 2: analysis of the data by individuals and by various methods and techniques

The major issues to be addressed are:

- Whose expertise should be used?.
- Which methodologies or techniques are appropriate?.
- Against what criteria or objectives are the analyses to be judged?.
- What data should be used or is relevant?.

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- Who are the relevant people to apply the techniques to the data?.

Decisions following from considerations of these issues could result in a greater understanding of the potential contribution and judgement of different experts, within and without the company; more tightly formulated objectives; and a greater understanding of the value of forecasting in general.

Establish and improve the process: foresight

Foresight activity seeks the subjective or intuitive opinions of a number of people with varying degrees of expertise. Opinions need to be collected without bias or misinterpretation. Using different techniques, some more structured than others, experts are asked to project their present knowledge towards how events and trends might develop in the future. They also need to consider what alternatives might be possible within the projected time frame. When setting up a foresight programme it is important to consider:

- What kind of expertise is relevant and how can it be obtained.
- What boundaries to the creativity of the process have to be imposed.
- How can the exercise be aligned to the needs of the organisation that is commissioning the study.

Specific techniques

Forecasting techniques

The formal forecasting techniques are standard components that are described in many textbooks on forecasting techniques (see specific techniques). Specific techniques for forecasting fall into two main categories, exploratory and normative. Information about each technique is available in various references.

- **Exploratory** techniques are primarily concerned with the analysis of historical data. Selected attributes such as functional performance, technical parameters, economic performance etc. are plotted against time. Since it is usually assumed that progress is evolutionary and that technological progress is not random, it is possible to generate characteristic curves or patterns from the data and from these patterns forecasts can be made with varying degrees of certainty. However, changes do occur and the influence and impact of new or surprise factors must not be disregarded. Examples of relevant exploratory techniques are:
 - S-curves
 - cycles
 - trend extrapolation
 - technology substitution— all of which rely on a large amount of statistical data, which may or may not be available freely.
- **Normative** techniques start by proposing a desired or possible state, such as the satisfaction of a market need or the achievement of a technological development, and work backwards from this to determine the steps necessary to reach the required outcome. The number of foreseeable paths of development from the present position to the objective could range from 'none', implying a completely new technology, to 'several'. Each feasible path to the objective is analysed for its

relevance and difficulty. Examples of relevant normative techniques are:

- [relevance trees](#)
- morphological analysis
- technology watch and technology monitoring
- [Delphi analysis](#)
- trend impact analysis
- technology substitution.

Information needed for these techniques is likely to be more firm-specific than that needed for exploratory techniques. Technology-watch in particular needs a proactive role to help the organisation identify and establish links with the most useful sources of information and opinion; typically these will be at the forefront of innovative activity.

Foresight techniques

The methods and systems used in foresight programmes are drawn from the forecasting field, particularly technology forecasting (see above).

Intuitive thinking is used more in technology foresight than in technology forecasting and is used in a comprehensive and structured form. All intuitive thinking methods are relevant to foresight activities, but only a few of the exploratory and normative methods used in forecasting are applicable to foresight. Which exploratory or normative method to use, under different circumstances, will depend on the requirements of each specific study.

The use of 'vision' is a form of intuitive thinking. When companies formulate a business strategy the vision of key individuals can play an important part. The value of this kind of input is increasingly acknowledged.

It is unlikely that any single method on its own will meet the needs of a foresight programme.

Other methods and techniques that can be used for foresighting include:

- The general classes of **cross-impact simulation**, which try to develop a qualitative understanding of the structure and interrelationships of the situation.
- **Relevance trees**, which investigate the dependence of technologies at one level to technologies at adjacent levels.

Both of these classes of methods provide some elements of semi-quantitative or judgmental analysis.

Patent analysis can be regarded as a specific foresight technique if the implications of the analysis are followed through.

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Relevance tree

Once an objective has been defined, a *relevance tree* technique can be used to investigate the relevance and feasibility of different ways of achieving it. It provides a means of exploring all the contributing technologies and approaches in a systematic way and highlights the alternative routes and choices that are available, and their consequences. If there is a critical gap which cannot be bridged with existing technology, it could signal an opportunity for a major technological innovation. Each route can then be assessed on criteria such as development cost, probability of success and lead time, and a decision taken relevant to company policy at that time. Expert opinion has to be employed to quantify the consequences and relevance of many of the steps, and there is no 'best' approach, because criteria will be company specific. A methodology using 'relevance numbers', which assigns to each path a proportional relevance with respect to other alternatives at the same level, is a useful tool for reaching a consensus, and for quantitatively comparing relative importance.

Delphi exercises

The *Delphi* technique is used where a consensus of expert opinion is required on the timing, probability and identification of future technological goals or consumer needs and the factors likely to affect their achievement. It is best used in making long-term forecasts and revealing how new technologies and other factors could trigger discontinuities in technological trajectories. The choice of experts and the identification of their level and area of expertise are important; the structuring of the questions is even more important. Experts in non-technological fields can be included to ensure that trends in economic, social and environmental fields are not overlooked.

The exercise usually consists of an iterative process of questionnaire and feedback among the respondents; this process finally yields a Delphi forecast of the range of experts' opinions on the probabilities of certain events occurring by a quoted time. The method seeks to nullify the disadvantage of face-to-face meetings at which there could be deference to authority or reputation, a reluctance to admit error, a desire to conform, or differences in persuasive ability. All of these could lead to an inaccurate consensus of opinion. The quality of the forecast is highly dependent on the expertise and calibre of the experts; how the experts are selected and how many should be consulted are important questions to be answered. If international experts are used, the exercise can take a considerable length of time, or the number of iterations may have to be curtailed. Although seeking a consensus may be important, adequate attention should be paid to views that differ radically 'from the norm' there may be important underlying reasons to justify such maverick views. With sufficient design, understanding and resources, most of the shortcomings of the Delphi technique can be overcome and it is a popular technique, particularly for national foresight programmes.

Benefits

Technology cannot be considered in isolation from environmental, social, economic and political factors and all these factors can affect a company's performance and outlook. The quality of decision-making in strategic planning can be improved by information on these factors and by the knowledge and experience learned from obtaining such information.

Forecasting and foresight extend and expand the benefits of near-term market intelligence and simultaneously stimulate learning and improvement practices.

Forecasting and foresight studies try to shed light upon the nature, magnitude, probability and timing of relevant scientific and technological developments. These can be opportunities or threats and might have a potential impact either on a single enterprise or on several or many enterprises collectively. They might have an impact on supply-chains, industry sectors or consumer markets.

It is sometimes important that national governments and international organisations, such as health and environmental agencies, should set up forecasting and foresight activities. These activities can complement the formal or informal planning, marketing or forecasting and foresight activities set up by business associations and/or individual companies. A co-incidental benefit of national or international studies that are conducted in a participative way is that they can facilitate networking between companies.

Much of the value of engaging in foresight activities at a company level lies in working through the processes themselves rather than just reading the results and formal reports arising from the exercise.

Foresight information can give greater legitimacy to vision statements. A common reason for a company to change its Chief Executive Officer is to inject a new vision into the organisation. Foresighting exercises can provide an alternative way to inject new vision; they are less dependent on the talent or inspiration of a few key individuals. A wide representation of employees can be involved in foresighting, or can learn about its impact and results; this has direct benefits since the vision is already communicated and better understood across the organisation. There are also indirect benefits in terms of empowerment, motivation and learning.

Watch out for

Forecasting must be a continuing activity if it is to bring maximum value and utility to a company. Systematic and longer time-span data will give an improved basis for conducting forecasts, and much can be learnt by comparing previous forecasts with what has actually happened in the intervening period. Forecasting need not be carried out continuously or frequently but it should be repeated at appropriate intervals.

Foresight can be an occasional activity but ideally should be continuous and integrated into the operating philosophy and culture of the company.

If forecasting exercises are not clearly understood and structured they can consume considerable resources of effort and expense.

Before beginning any forecasting exercise it is important to review the need for a forward look, and then match this to the resources available. The quality and usefulness of results are very dependent on the quality of information obtained and the expertise with which it is analysed and used. Deploying too many resources in futures studies can be counter-productive.

The results of the first attempts at forecasting or foresighting may be disappointing. For a variety of reasons there may be a lack of conviction in the early stages of establishing the process. For example: information may not be sufficiently comprehensive or relevant; new sources of data may have to be identified; new contacts or networks may have to be established; the relevance and value of different

techniques may have to be reviewed. However, the process should not be abandoned too hastily. Further work will lead to better results. The best way to learn the skills and to evaluate the most useful and relevant sources, inputs and methods for each company, is to actually do it.

A vision or mission statement or defined core competence can narrow the focus of futures studies, but care needs to be taken to prevent the focus becoming too narrow. The value of any study would be reduced if mindsets became too narrow or closed; companies would under such circumstances fail to recognise the potential relevance of certain trends and developments.