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TECHNOLOGY MONITORING

Principles and practices

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

economy environment employment

Principles and Practices of Technology Monitoring

United Nations Industrial Development Organization
Vienna, 2001

Numbers in square brackets appearing in the text refer to chapter endnotes.

This is an advance version of a forthcoming sales publication.

Preface

Technology monitoring is a topic of growing interest. It is a subject area seen as an increasingly important dimension of decision-making and is of particular interest to policy makers of developing countries and enterprise managers who operate in an environment of rapid industrial and technological change. The United Nations Industrial Development Organization (UNIDO) is increasingly being asked by member States to provide information, advice and guidance on monitoring technological progress and change. In response to this need, the present document has been prepared to provide a review of principles and practices related to technology monitoring, focusing on the enterprise level.

Principles and Practices of Technology Monitoring was prepared by the United Nations Industrial Development Organization, Investment and Technology Promotion Branch under the supervision of Dr. R. Seidl da Fonseca. Dr. B. Bowonder, a consultant for UNIDO, drafted the major portion of the text and Dr. B. M. Van Vliet, also a consultant, reviewed and contributed text.

Other experts provided advice, comments and suggestions for improvement, namely Dr. T. Miyake. Dr. Andreas Botha of Dynamic Strategy Modeling CC, South Africa, provided relevant suggestions and comments regarding the structure and content of the book.

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Overview

Technology monitoring is the comprehensive analysis of technological trends in a specific field for the identification of existing or emerging technologies that have excellent commercial potential. Rapid technological change and global competition have made it necessary to put in place regular systems both for monitoring technological changes and for indicating implications for business. In a competitive business context, technology monitoring acts as an early warning and as a decision support system.

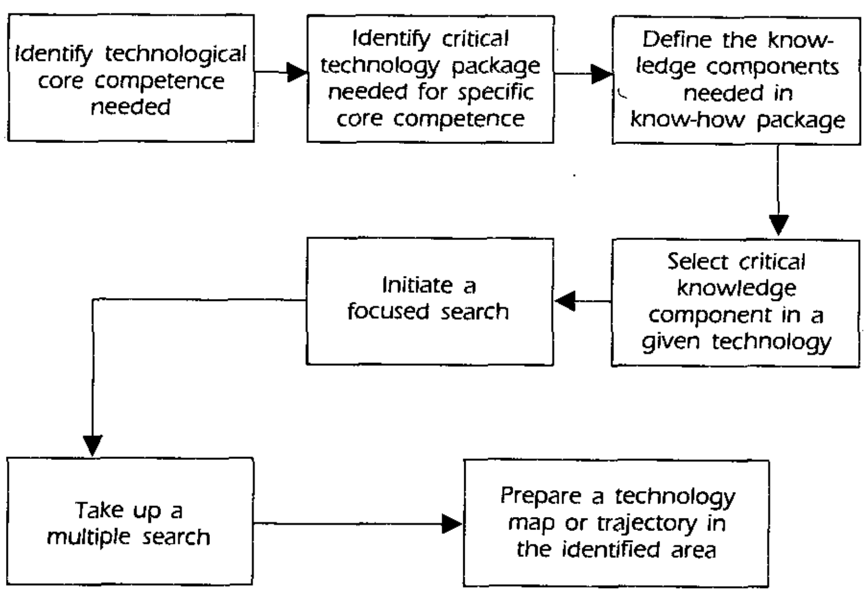
Figure 1. Use of monitoring

	Strategic Orientation	
Focus	Competitive	Futuristic
Innovation	Competitive intelligence	Technology monitoring
Problem solving	Random search	Technology scanning

The strategic value of monitoring is that it expands the technological choice in decision-making, thereby improving the options for commercial exploitation of new technology. Technology monitoring is a component of strategic information support for technology-oriented decision-making. Monitoring important technological developments can provide a strong foundation for informed company choices and actions. Technology monitoring facilitates the acquisition of well-adapted technological choices by identifying sound options and sources, as well as assisting in objective evaluations of alternatives.

Technology monitoring can help developing countries in a variety of ways, such as identifying potential areas on which to focus. The institutionalization of technology monitoring will help in stimulating the consultancy culture and its rapid diffusion. Monitoring helps enterprises focus on country-specific needs so that particular normative technological requirements can be addressed. Monitoring at the national level and the global regional level will help developing countries disseminate information on the potential technologies and products to global markets as well as keep pace with information about emerging markets. Technology monitoring and the dissemination of results will facilitate the development of entrepreneurs. Technology monitoring facilitates the stimulation of innovation as well as the acceptance of new innovations in developing countries.

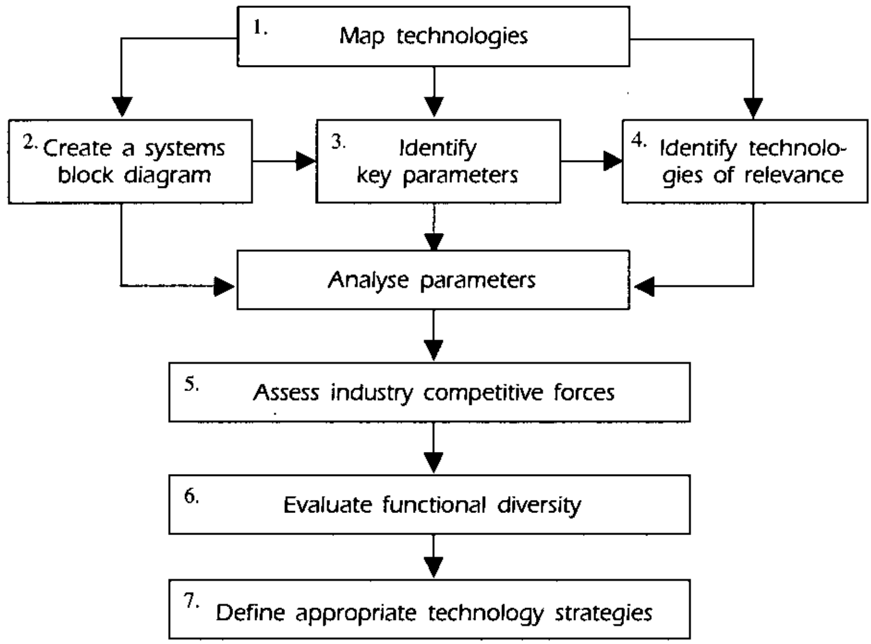
Figure 2. Sequence of technology monitoring



Technology monitoring involves:

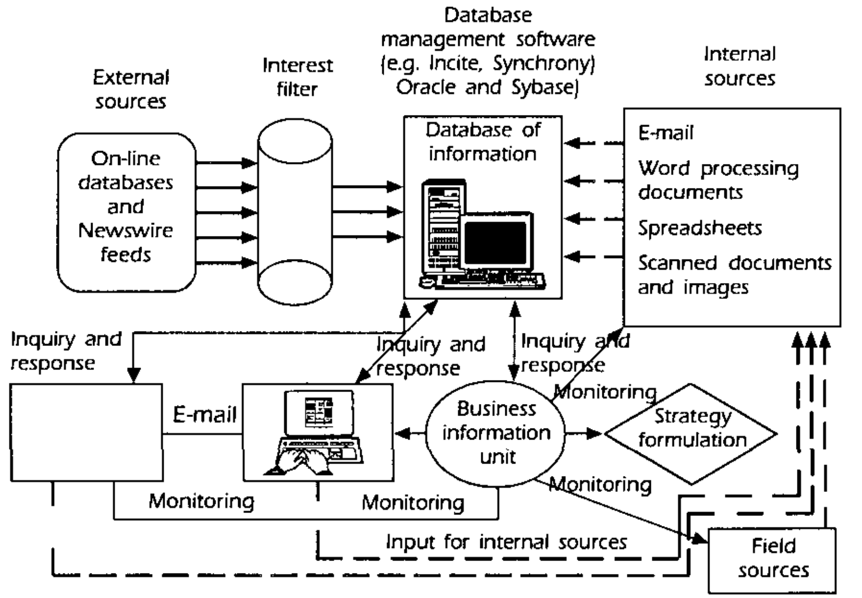
- Determining the focus of monitoring objectives
- Defining the technology and mapping the context
- Devising a monitoring strategy
- Analysing and interpreting the information
- Communicating the results

Figure 3. The seven steps of technology mapping



Source: R. A. Goodman and M. W. Lawless, *Technology and Strategy*, Oxford University Press, New York, 1994.

Figure 4. A technology monitoring system at enterprise level



The major tools used for technological monitoring are:

- ❑ Mapping the technological trajectory
- ❑ Scanning technological developments
- ❑ Modelling
- ❑ Subjective assessment

Technology monitoring requires four types of distinct competencies:

- ❑ Detecting signals of technological change
- ❑ Assessing the direction of the technology trajectory
- ❑ Identifying specific technologies with growth potential
- ❑ Implementing specific action programmes that exploit emerging technologies with high potential

Technology monitoring is being practised and effectively used at global regional, national and enterprise levels. One of the ways of reducing the cost of performing technology monitoring is to pool monitoring efforts and share the scanning costs through cooperative arrangements among developing countries.

In a global economy characterized by competition, complexity and uncertainty, the only way to reduce the business risk is to anticipate change and encourage organizational learning processes.

The competitiveness of a firm or a country depends on its ability to link aspects of technology such as monitoring, learning, creation and diffusion in a reinforcing manner.

Technology monitoring facilitates institutional learning in multiple ways, by:

- ❑ Triggering constructive conflict
- ❑ Encouraging "unlearning" old beliefs and concepts
- ❑ Providing new ideas for action
- ❑ Communicating the nature of change
- ❑ Unravelling new opportunities
- ❑ Revealing threats of inaction
- ❑ Bringing together agents of change
- ❑ Initiating further enquiry
- ❑ Facilitating learning from others

Introduction

Background

The rapid rate of industrialization and the liberalization of the global economy have made technology a major component of the industrialization process. For this reason, technology management has become a vital competence needed by decision makers, industrial planners as well as senior executives. Technology monitoring is a major element of technology management. Indeed, in some respects, it is the starting point for technology management. Identifying emerging technological options, evaluating opportunities in technology, making informed choices, and forecasting and assessing technology are aspects of a diverse and changing environment. Keeping pace with such changes requires continuous monitoring of trends in technology. The present manual has been prepared as a support to decision makers whose focus is on monitoring technological trends.

Definition and concept of technology monitoring

Science, technology and innovation are driving forces of economic growth. Changes in technology have transformed the global economic fabric over the last 200 years. The 1970s and 1980s have witnessed phenomenal changes in economic growth patterns caused by emerging technologies. Those countries that have been able to take advantage of emerging technologies are also the ones that have been growing rapidly.

Innovative enterprises are the engines of growth in any economic system [1]. Developing countries need to stimulate the growth of firms that generate and use innovation. In the current economic context, technology-based innovations are becoming the basis for creating and sustaining competitiveness. Internationally, high technology firms are growing rapidly, as are their industrial counterparts in international trade, in sectors such as:

- ❑ Computing
- ❑ Telecommunications
- ❑ Semiconductors
- ❑ Automobiles
- ❑ Pharmaceuticals

The volume of products based on low technology is not growing rapidly whereas technology-based products are growing rapidly in international trade. In response to recent changes in the world economy, developing countries need to evolve institutional reforms to respond to such changes. The same kinds of institutional responses that were used earlier cannot help firms to cope with the current pace of competition. The emerging business environment is characterized by:

- ❑ Aggressive competitors
- ❑ Demanding customers
- ❑ Emerging opportunities in high technology, globally
- ❑ Rapidly evolving technology
- ❑ Enabling governmental support (in place of protection)
- ❑ Advanced infrastructure

Figure 5. Business environment

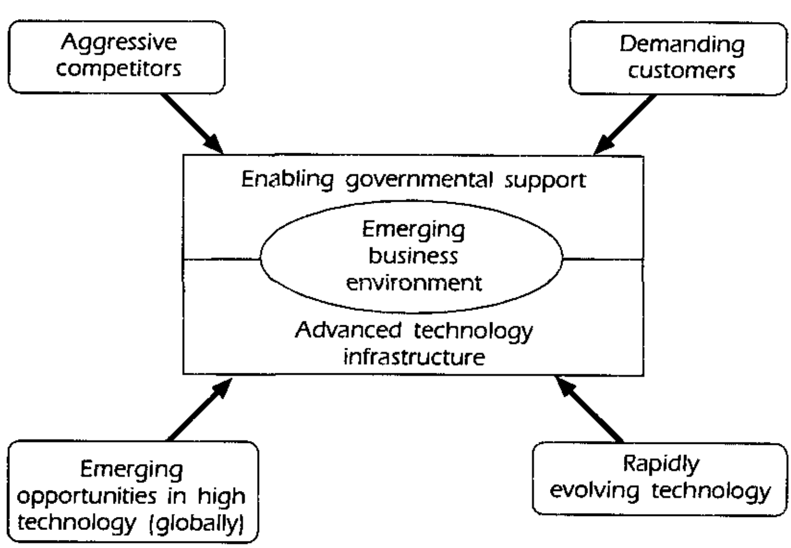


Table 1. Elements of the present business context

Aspect	*Characteristic*
Technology	Rapidly evolving Environmentally friendly User-friendly Resource-saving Intelligent
Competitors	Aggressive Global Innovative Alliancing Strong
Customers	Demanding Knowledgeable and informed Quality-conscious Variety-seeking
Opportunities	Emerging Global
Government	Enabling Supportive

> By monitoring the life cycle of existing and emerging technologies, it may be possible to identify technologies that are likely to have significant commercial impact well before their widespread use.

The winners in the race will be those capable of monitoring, understanding and reacting effectively to the dynamics of the business environment [2]. The current context is schematically depicted below in figure 5 and table 1.

The collection and analysis of technological information relating to markets, new technologies, customers and broad social trends are becoming essential tools for sustaining industrial competitiveness. The basic logic of monitoring is that any technology has a life cycle consisting of idea, concept, design, prototype, manufacturing, product diffusion and decline.

> Technology monitoring is a directed and anticipatory search activity for understanding the dynamic interactions of technology and business.

Entrepreneurs look ahead and often enter the market first, paving the way for established firms. Continuous monitoring helps firms to respond to changes in the business environment in a systematic fashion. Monitoring does not eliminate the uncertainty, but it warns executives of impending threats and informs them of new opportunities in advance of competition. Mimicking innovative ideas and practices may not be sustainable in the longer term. Indeed, a follower firm can copy and enter into the market using imitation mode; however, relying on rents from copied technology can be self-destructive. Monitoring helps businesses move from imitation to true innovation by making transparent the dynamics of technology. In this way, organizational learning takes place.

Monitoring technologies can facilitate decision-making that relates to technological choice, technological transfer, technology forecasting and technology assimilation. Technology monitoring is no longer merely a fashionable obsession of business school academics; it is a critical input for survival in a competitive context.

Monitoring, scanning, forecasting and assessing technology

Technological change is an evolutionary process [3] in which knowledge generation, knowledge accumulation and knowledge evolution interact. In an intensely competitive evolutionary environment, three processes are critical for survival, namely:

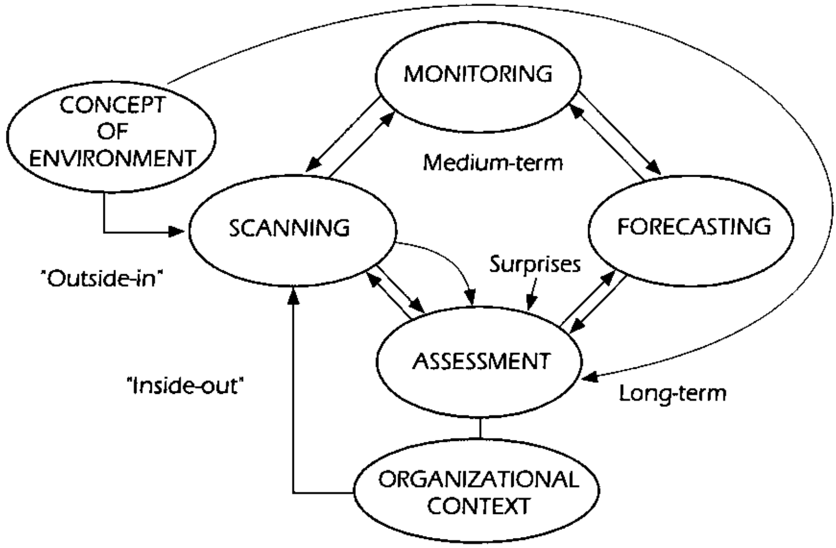
- Selecting strategic options
- Learning adaptive behaviour
- Adapting to change

Firms that can survive in a competitive context are those that have the ability to:

- Select superior technological trajectories ahead of competitors or develop their own products in a specific field
- Learn faster than others
- Adapt to the changing environment and cope with competition

The second implication of the emergence of a competitive environment is that the sources of Ricardian or monopolistic rents will be fewer and the most attractive options will be rents from innovation and entrepreneurship. The rapidly changing industrial production patterns and

Figure 6. Technology monitoring in the organizational context



trade patterns clearly indicate that unless developing countries adopt new technologies and facilitate economic growth, the gap between developing and developed countries will continue to widen. In the top 200 companies of the world, ranked in order of research and development (R & D) expenditure, only one major corporation is from a developing country. The United Nations Industrial Development Organization (UNIDO) has identified technology promotion as one of the major areas needing immediate attention [4]. The global industrial production system and the global trade system are evolving continuously towards a higher degree of technological complexity. In view of this, it is important for firms in developing countries to develop institutional capabilities for monitoring, assessing and forecasting the emerging changes and opportunities in technology on a continuing basis. Conducting technology monitoring, forecasting and assessment will help in sharpening the strategic focus of the activities of the firms, so that core competencies are less likely to be eroded.

The present manual focuses on technology monitoring. It is the starting point of technology assessment and forecasting exercises as shown in figure 6 above. Scanning is a major component in the monitoring process that leads to technology forecasting [5]. Technology monitoring serves as a tool for sharpening the strategic focus which is the basis of competitiveness.

Need for technology monitoring

In a competitive context, it is necessary to regularly monitor trends in technology so as to assess internal strengths and weaknesses in addition to external, competitive threats and opportunities. There are six major reasons for having an institutional monitoring system:

- There has been a rapid increase in global competition. Protective environments are being replaced by competitive environments. If firms are to survive and grow, competitive threats need to be monitored and analysed continuously. Monitoring therefore helps firms to understand technological trends and to reduce surprises. Time has become a major competitive element which differentiates winners and losers;
- There has been a rapid increase in international licensing. Licensing has become a major source of industrial growth. Monitoring helps in identifying areas with high growth potential, thereby facilitating the process of licensing and technology diffusion;
- Shortening the product life cycle reduces the required response time for new product development. Because of this, new product failures are becoming more risky. This means that firms need to time their product introduction more systematically;
- The cost of innovation is increasing rapidly and firms need to improve their efficiency in this area. Monitoring helps reduce the "reinventing the wheel" syndrome;
- A large number of innovative ideas created globally are wasted, as there are few initiatives that filter through or identify new technological opportunities. Monitoring innovative ideas that are generated around the globe in a systematic manner helps firms introduce new products through the transfer of technology among regions. This will increase entrepreneurship and strategic partnerships;
- There has been an information overload regarding new technologies. Without a comprehensive institutional arrangement for

> Technology monitoring is the comprehensive analysis of technological trends in a specific field for the identification of existing or emerging technologies with excellent commercial potential.

linking technical and commercial information decisions regarding investments, joint ventures, alliances, technology acquisition and R & D licensing, decisions tend to become ad hoc and intuitive. Technology monitoring helps to develop a decision support system by integrating technical and commercial information.

Hence, it is necessary to design and implement a technology monitoring system that helps executives, industry planners and consultants to manage the information maze relating to the technology trajectory. The concept of technology monitoring has been used in the present manual as a decision support system for technology-oriented decisions.

Evolution of technology monitoring

For many years, one of the qualities that distinguished successful businesses was the ability of their executives and managers to think quickly and stay on top. This was necessary to influence the course of the economic, social, political and technological conditions of the environment in which they operated [6]. Competition for market and ownership control has intensified to the point where the competitive environment of business is changing more rapidly and less predictably than at any time since the industrial revolution began. Technology monitoring methods and processes evolved over time to respond to such issues. In the 1960s, when technology was not changing as rapidly, monitoring was a part of environmental analysis. As market competition increased, monitoring became a more directed search; this was termed competitive analysis and intelligence [7]. In the beginning of the 1980s, technology was recognized as a major driving force of competition in such areas as automobiles, electronics, computers, drugs, aerospace and new materials. It became necessary to initiate institutional systems for understanding the driving forces of change.

An emerging technology casts shadows and becomes visible to the expert eye long before it has significant impact [8]. Bright indicated that new technology emerges from an idea, is translated into physical reality, and is then applied and adopted at a gradual rate, rather than instantaneously. It follows that it may be possible and should be useful to monitor such dynamics so as to react wisely and in a more informed manner. Technology monitoring is defined as monitoring the environment in order to detect the beginnings, progress and likely consequences of new advances in technology [2]. The four activities involved in monitoring are:

- Searching the environment for signals that may become forerunners of significant technological change
- Identifying possible alternative consequences if these signals are not spurious and if the trends that they suggest continue
- Choosing those parameters, policies, events and decisions that should be followed in order to verify the true speed and direction of technology and effects of employing that technology
- Presenting the data from the above steps in a timely and appropriate manner for use in decisions about the organization's reaction [2].

It can be seen that the essence of technology monitoring is evaluation and continuous review of impending trends in technology.

With the intensification of global competition and the evolution of computer technology along with on-line databases and the Internet revolution, technology monitoring has become a regular element of decision support systems. There is an information overload in the environment which can be managed only by having institutionalized systems for understanding the pace and direction of technology. For example, when Microsoft recognized the importance of the Internet, it responded by providing an Internet browser.

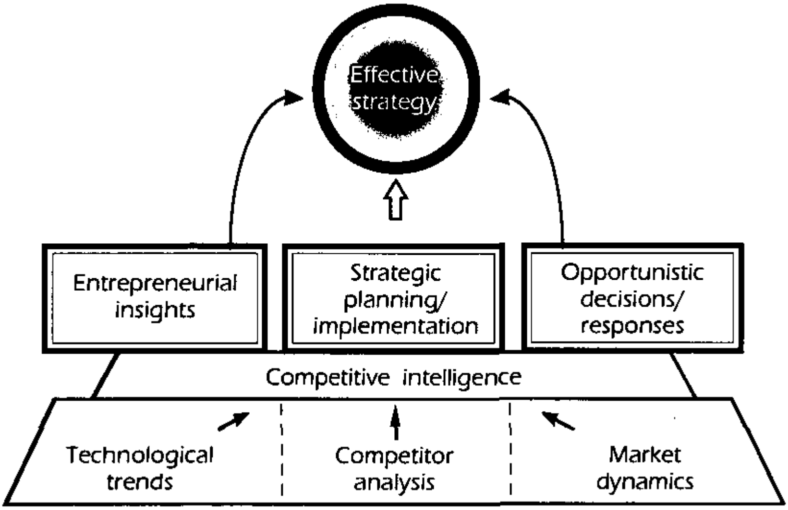
Technology monitoring as a decision support tool

Technology monitoring is a decision support tool. The technological landscape is obscure, unpredictable and dynamic [6]. When the performance characteristics of a technology are charted over time, they reveal that improvements occur in fits and starts. The strategic essence of technology monitoring emphasizes developing the following three elements:

- An information support system for facing and understanding competing technologies
- An information support system for understanding the winds of technological change
- A management or business process for exploiting new technological opportunities

A strategic decision support system will be required that can provide information for preparing a map of technology, strategic options and a directional focus.

Figure 7. Inputs for strategy making



Historically, firms have always experienced communication problems between technology-acquisition activities, usually in the form of R & D, and between business and financial strategy functions. The role of technology monitoring in the strategic planning process is given in figure 7 above.

The technology monitoring system provides information support for answering the following questions:

- ❑ How can the future business and the technology environment be described?
- ❑ What are the technology needs of your products and processes?
- ❑ What are the favoured technology candidates and how do they compare?
- ❑ What are the major sources for acquiring the identified technologies?
- ❑ Are there any major regulatory or intellectual property issues concerning the technology options?
- ❑ What are the problems that are likely to be faced while implementing a technology strategy?

Technology monitoring is an entirely new activity and it is much more than technology scanning. Libraries collect and collate information but they do not usually evaluate it. Technology monitoring provides inputs for a variety of strategic decisions relating to any specified technology of interest to a corporation.

Conclusion

Fast technological change and global competition have made regular systems necessary for monitoring both technological changes as well as implications for business. Executives need to prepare strategic road maps before taking strategic decisions and monitoring inputs for preparing the maps. This helps in clarifying the possible future technology trajectory, thereby reducing the uncertainties associated with the choice in technology, decision-making, technology negotiating and choices in long-term investment.

Technology monitoring is an insurance against environmental uncertainty. It is a value-added decision support system for making effective decisions relating to technology. In a competitive business

Figure 8. Structure of the manual

Introductory issues	Preface Why was this manual created?	Introduction What is it about?	Chapter 1: The strategic value of technology monitoring What value does it provide?	Chapter 2: Conceptual framework for technology monitoring Where does it fit in?
Mechanics	Chapter 3: Technology monitoring methodology How to?	Chapter 4: Technology monitoring tools How do I do it?	Chapter 5: Skills and competencies required for technology monitoring What do I neeed to be able to do?	
Application	Chapter 6: Implementation of technology monitoring How do I make a difference?	Chapter 7: Organization for technology monitoring How do I improve the probability of success?		
Supporting infrastructure	Chapter 8: Facilitating institutional learning and technology monitoring How can I learn faster?	Annex II Country experiences and case studies What has been done before?		

Source: Suggestion proposed by B. M. Van Vliet.

situation, monitoring acts both as an early warning system and as a decision support system. The structure of the manual is presented in figure 8 above, showing flow and logic. For the purposes of the manual, technology monitoring is defined as the comprehensive analysis of technological trends in a specific field for the identification of existing or emerging technologies that have excellent commercial potential.

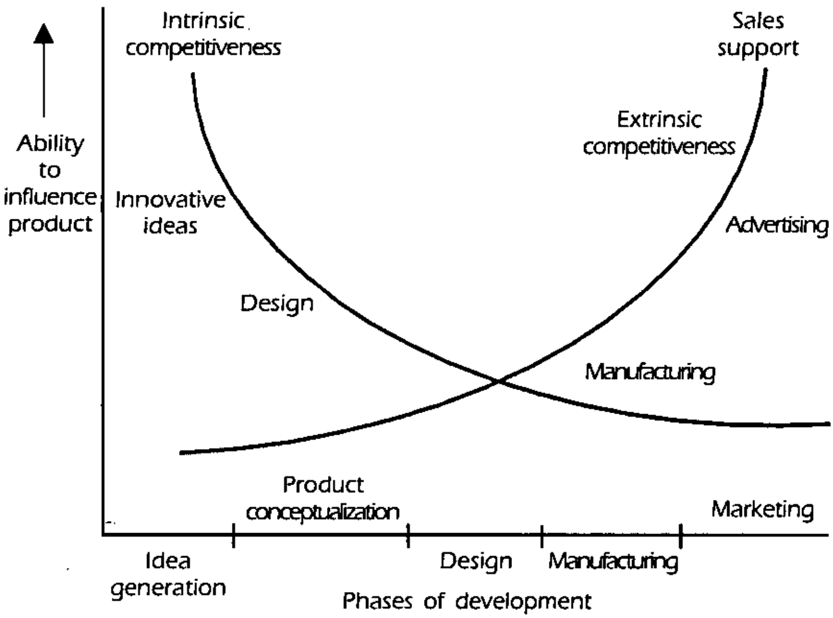
References

1. J. A. Schumpeter, *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle* (Redvers Opie, trans.), Harvard University Press, Cambridge, Massachusetts, 1934.
2. B. Bowonder, "Technology Monitoring at the Enterprise Level", paper prepared for the Meeting on Cooperation in Technology Monitoring in Developing Countries, UNIDO, Vienna, November 1994.
3. R. R. Nelson and S. G. Winter, *An Evolutionary Theory of Economic Change*, Harvard University Press, Cambridge, Massachusetts, 1982.
4. UNIDO, Meeting Report, Meeting on Cooperation in Technology Monitoring in Developing Countries, November 1994, pp. 22-25.
5. V. K. Narayan and L. Fahey, *Environmental Analysis for Strategy Formulation* (W. R. King and D. I. Cleland, eds.), *Strategic Planning Management Handbook*, Van Nostrand, New York, 1987.
6. J. D. Stoffels, *Strategic Issues Management: A Comprehensive Guide to Environmental Scanning*, Pergamon, Oxford, 1994.
7. L. M. Fuld, *The New Competitor Intelligence: The Complete Resource for Finding, Analyzing, and Using Information About Your Competitors*, Wiley, New York, 1995.
8. J. R. Bright, *Forecasting by Monitoring Signals of Technological Change* (J. R. Bright and M. E. F. Schoeman, eds.), Prentice Hall, Englewood Cliffs, New Jersey, 1973.

1. The strategic value of technology monitoring

Technology is the basis of intrinsic competitiveness. It is the internal competence to develop new products, new processes, new applications and new services. As one moves down the innovation chain, the strategic leverage to influence product parameters is reduced. Innovative ideas have an intrinsic premium in a competitive context, as shown in figure 9 below. Compared with this, complementary competencies, such as manufacturing, advertising and sales support, are extrinsic to competitiveness. Firstly, the harmonization of regulations pertaining to global intellectual property rights makes it possible for companies and individuals to protect new ideas, designs and innovations for longer periods. Secondly, global competition is driven by technology, thus the first entrant has enormous strategic advantages. Technology monitoring helps in expanding the strategic options available to a firm for acquiring or

Figure 9. Technology and competitiveness



Source: B. Bowonder and T. Miyake, *Creativity and Innovation Management*, vol. 3, 1994.

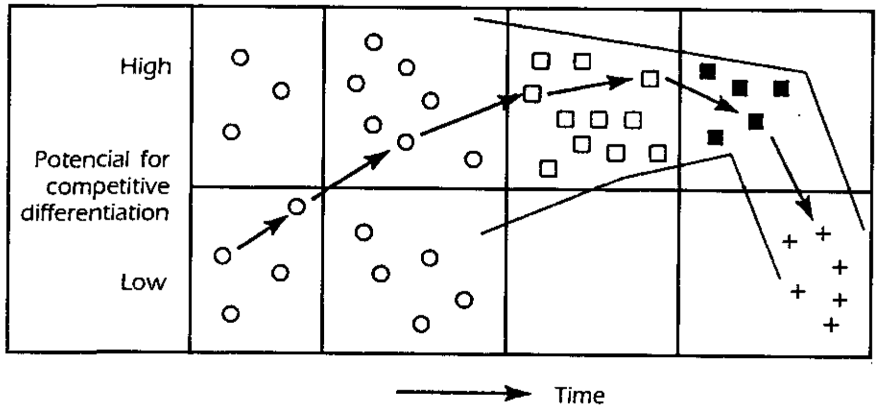
developing a new technology. Thirdly, technology monitoring helps in reducing the time from concept to product delivery by providing a regular flow of ideas for product or process innovation.

Conceptual basis for monitoring

Technology monitoring acts as an input for anticipating future technological options in advance of competition. Technology monitoring is defined as the scanning, prospective evaluation and monitoring of new technologies early in their life cycle. Conceptually, this can be shown as a funnel, as in figure 10 below. The steps involved are:

- ❑ Scanning the scientific base for promising technologies that will have practical use;
- ❑ Scanning and monitoring emerging technologies that are likely to be commercially useful;
- ❑ Monitoring and evaluating technologies, products or applications that have high commercial potential;
- ❑ Identifying and harnessing key technologies or products that can help in competitive differentiation so as to be ahead of competitors;
- ❑ Continuous monitoring and evaluating of technologies, products or processes that can be used through licensed manufacturing or for supply sourcing through subcontracting.

Figure 10. Scanning and monitoring new technologies



Key: ■ Key technologies ☐ Pacing technologies ○ Emerging technologies + Base technologies

Technology follows an evolutionary trajectory. The early patterns of evolution can be observed or used for predicting later event behaviour. In the past, industry forecasters screened and monitored emerging technologies in order to identify the development funnel for commercialization. Technology forecasting was considered to be an art or a very sophisticated technique, understood only by science and technology experts [1]. Linear thinking of this kind and a technology-driven approach still dominate certain industries and Governments; however, some rapidly growing, innovative and entrepreneurial firms are using monitoring concomitant with intuitive judgements to predict trends.

The third-generation approach, currently in vogue, considers technology monitoring and forecasting as needs-based and value-driven. By linking users in the early phase of the innovation chain, the new approach attempts to achieve the following:

- As a result of the above, the time between idea-generation and its commercial utilization is reduced;
- To facilitate interaction between technology users and generators, thereby reducing problems during commercialization of products by providing downstream linkages for the commercialization of technology or for commercial utilization.

Strategic value of monitoring

Schumpeter has shown that innovation is the basis of economic growth [2]. Innovation produces new products and demand for new products leads to

Figure 11. Use of monitoring

	Strategic Orientation	
Focus	Competitive	Futuristic
Innovation	Competitive intelligence	Technology monitoring
Problem solving	Random search	Technology scanning

process innovation. As technology diffuses, new applications emerge and technology evolves through creative destruction. Schumpeter defined innovation in a broad sense. Subsequent to this work, a variety of types of innovation [3] have been identified, which include:

- Product innovation
- Process innovation
- Application innovation
- System innovation
- Core competence extension
- Technology fusion

The main logic of using innovation is that a firm adds value by applying technology advances. The strategic value of monitoring is that it improves the technology selection process, thereby expanding options for commercial exploitation of new technology. In strategic management terms, technology monitoring can be used in four ways, as shown in figure 11 above.

Technology monitoring may therefore be used as:

- A focus for innovation with the goal of gaining a competitive advantage
- A focus for innovation with a goal of gaining insight into future trends
- Problem-solving for keeping ahead of competition
- Problem-solving with a narrow future orientation

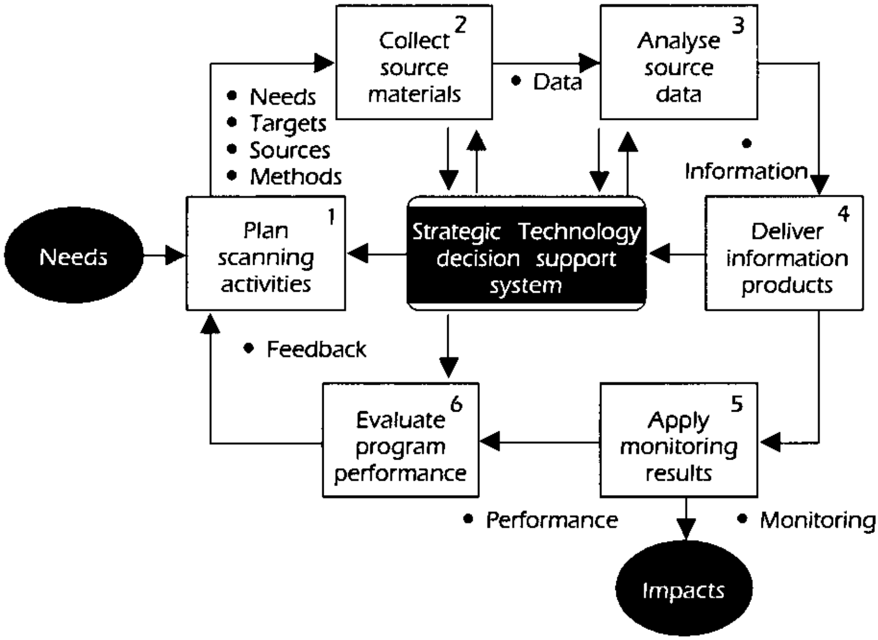
In other words, it is about gaining just enough insight into future trends to be able to solve a particular problem.

The implication is that technology monitoring needs a strong future orientation so as to stimulate innovations.

Monitoring, scanning, forecasting and assessing

Technology monitoring is a component of strategic information support for technology. Some of the basic definitions used in the area of strategic decision support systems are given in box 1 below. The technological intelligence activities covered do not include any illegal or unethical activities such as industrial espionage [4]. Monitoring of important technical developments can provide a strong foundation for informed choices and actions on the part of

Figure 12. Strategic technology decision support system



enterprises. A typical decision support system relating to strategic technology is given in figure 12. It facilitates acquisition of the best technology option through identification of the right sources and the objective evaluation of alternatives.

Scanning refers to searching for signals of technology change so as to identify business opportunities. Technology monitoring is purposive scanning combined with an evaluative assessment of trends. Technology forecasting is the prediction of future performance characteristics of machines, systems and procedures using monitoring results and analysis trends. Technology assessment is the structured, systematic and detailed analysis of the implications of technology. A comparative analysis of those four activities is given in table 2.

Historically, technology forecasting came from large institutions such as the United States Department of Defense. The focus was to reduce technology uncertainty by anticipating emerging technological changes. Environmental scanning was used by strategic planners to develop an integrated and contingent view of the future, taking into account economic, social, technological, regulatory and consumer trends. Competitive intelligence emerged as a tool for systematically assessing the strengths and weaknesses of competitors. Most of those tools have an overlapping

Box 1. Basic definitions of technology monitoring activities in business

Technical intelligence	Business-sensitive information on scientific or technological threats or opportunities that, if disclosed or used improperly, could be harmful to an organization's business health.
S&T scanning	Constant surveillance and review of information from a broad set of data sources to identify technical developments and changes that could be important to a firm. Frequently, scanning identifies subjects that are then examined in more depth in the monitoring or assessment process.
S&T monitoring	Continuous seeking, interpretation and provision of access to information on selected technical areas. Successful monitoring does not provide a steady stream of information, but instead highlights key events and changes in the form of "red flags". Monitoring activity becomes a repository of information about continuous changes, while the system users are informed about changes that warrant special attention.
S&T assessment or evaluation	Systematic analysis of the impacts or potential value of a scientific or technological development to determine if some form of management action (e.g. further attention, acquisition, investment or transfer) is warranted and to recommend action. The need for an assessment or evaluation would arise as a result of a finding of the monitoring programme or from other independent sources within the business.
S&T acquisition or transfer	Conversion of science and technology developments into intellectual property that can be used to create value for the business. Generally, the development becomes intellectual property when the idea has been documented and the potential application of the development has been defined.
S&T internalization	Conversion of S&T knowledge or intellectual property into a business asset by incorporating it into routine firm operations. Examples include using an S&T finding to reduce costs or to create a new product, allowing entry into a new market or expansion market share.

Source: W.B. Ashton and G.S. Stacey, "Technical Intelligence in Business: Understanding Technology Threats and Opportunities", *International Journal of Technology Management*, vol. 10, No. 1, 1995.

focus. Technology monitoring is a combination of both environmental scanning and technology forecasting with a sharper focus on current utilization. Technology monitoring is a valuable tool for large corporations as well as government decision makers. In addition, it is a support tool for small enterprises or entrepreneurs looking for opportunities. It provides a strong information base for making sound choices.

Table 2. Monitoring, scanning, forecasting and assessing technology

	Monitoring	*Scanning*	*Forecasting*	*Assessing*
Focus	Track specific trends and events	Open-end viewing of environment to identify signals	Project future patterns and events	Derive implications for organizations
Goal	Confirm or disconfirm trends	Detect change already underway	Develop possible and plausible projections of future	Derive implications for organizations
Scope	Specific trends, issues, events	Broad, general environment	Limited to trends and issues deemed worthy of forecasting	Critical implications for organizations
Time horizon	Real time	Retrospective	Prospective	Prospective and current
Approach	Systematic and structural	Unconditioned viewing of heterogeneity of stimuli	Systematic and structural	Systematic, structured and detailed
Data characteristics	Relatively bounded gains in precision	Unbounded and imprecise, vague and ambiguous	Quite specific	Very specific
Data interpretation	Weighing evidence, detailing patterns	Acts of perception, intuitive reasoning	Judgements about inferences	Judgements about inferences and/or implications
Data sources	Focused reading, selective use of individuals, focus groups	Broad reading, consulting many types of experts inside and outside	Outputs of monitoring, collected via forecasting techniques	Forecasts, internal strategies, competitive context and so forth
Outputs	Specification of trends, identification of scanning needs	Signals of potential change, detection of change underway	Alternative forecast: identification of scanning and monetary needs	Specific organization implications
Transition	Judgements regarding relevance to specific organization	Hunches regarding salience and importance	Inputs to decisions and decision-making processes	Action plans
Organizational outcomes	Consideration and detailing of specific findings, time for developing flexibility	Awareness of general environment	Useful decision models and processes	Specific actions

Source: V. K. Narayan and L. Fahey, "Environmental Analysis for Strategy Formulation", (Eds. W. R. King and D. I. Cleland), *Strategic Planning Management Handbook*, Van Nostrand, New York, 1987.

Technology monitoring and innovation

"Innovate or evaporate" is the corporate dictum today. Innovation is defined as anything new undertaken by an entrepreneur or an executive that enhances the competitive advantages of an enterprise [5]. Technology monitoring and the process of innovation are closely interrelated. Technology monitoring stimulates the innovation process and reduces the innovation cycle time. Today, corporations face mostly innovation-driven competition. The process of innovation has become concurrent with the process of idea generation, conceptual design, detailed design, engineering, field trials, manufacturing process design, manufacturing, marketing and life cycle support—all of which overlap to a degree

> "Innovation has become the most critical aspect of corporate management in a dynamically changing world in which increasing competition, cooperative projects, strategic alliances, creative destruction and shortening the idea-to-customer-cycle time are forcing firms as well as nations to adopt strategies for coping with change."

Technology monitoring [6] facilitates the innovation process in a variety of ways, including by:

- Anticipating changes in the market so that advance action can be initiated to minimize risk;
- Anticipating actions of the competitors so that a reactive competitive posture is avoided;
- Identifying new or potential competitors so that their action can be neutralized;
- Learning from the success and failure of innovation so that the same mistakes are not repeated;
- Identifying potential partners for strategic alliances for new product development or access to new markets;
- Learning about emerging technologies, products and processes that affect business;
- Identifying new business opportunities ahead of others.

Technology monitoring can trigger organizational learning that helps to increase innovativeness as well as facilitate diffusion of innovation.

Thus, technology monitoring can help to improve the linkages between adopting technological change and growth of industrial output.

> *"It is not the strongest of the species who survive nor the most intelligent, but the ones most responsive to change."*
>
> Charles Darwin

Technology monitoring makes executives and decision makers more responsive to change by institutionalizing a system to monitor technological changes, to analyse the implications of such changes and then to communicate them to the decision makers. This also stimulates entrepreneurship and diffusion of technology for newer fields or newer applications. The major relevance of technology monitoring is that it prepares executives to understand and comprehend technological opportunities through a regular institutional mechanism for anticipating change.

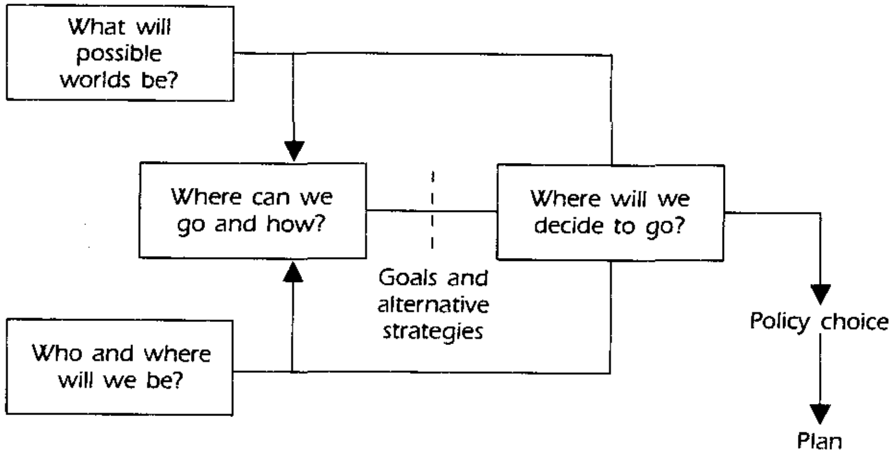
Technology monitoring facilitates the development of a mechanism for understanding the signals of change and for interpreting them in a consistent manner in a variety of situations. Some advantages of technology monitoring include:

- Inducing executives to look beyond today
- Helping in identifying opportunities for entrepreneurs
- Assisting in the search for compatible partners with complementary interests
- Providing more new-product ideas
- Facilitating change by making the decision makers aware of the implications of continuing with the business-as-usual scenario
- Indicating gaps in information availability when choosing technologies or making technological decisions

Conclusion

Technology monitoring can provide answers to a number of strategic issues. Some strategic uses of technology monitoring [7] are shown schematically in figure 13 below. Monitoring provides inputs for many of the issues indicated.

Figure 13. Strategic uses of technology monitoring



References

1. A. Gerybadze, "Technology Forecasting as a Process of Organizational Intelligence", *R & D Management*, vol. 24, No. 2, 1994, pp. 131-140.
2. R. R. Nelson and S. G. Winter, *An Evolutionary Theory of Economic Change*, Belknap Press of Harvard University Press, Cambridge, Massachusetts, 1982.
3. B. Bowonder and T. Miyake, "Innovations and Strategic Management: A Case Study of Hitachi Ltd.", *Technology Analysis and Strategic Management*, vol. 6, No. 1, 1994, pp. 55-81.
4. W. B. Ashton and G. S. Stacey, "Technical Intelligence in Business", *International Journal of Technology Management*, vol. 10, No. 1, 1995, pp. 79-104.
5. M. J. Manimala, "Entrepreneurial Innovation: Beyond Schumpeter", *Creativity and Innovation Management*, vol. 1, No. 1, 1992, pp. 46-85.
6. L. Kahaner, *Competitive Intelligence: From Black Ops to Boardrooms: How Businesses Gather, Analyze, and Use Information to Succeed in the Global Marketplace*, Simon & Schuster, New York, 1996.
7. L. Gerardin, "Study of Alternative Futures", *A Guide to Practical Technology Forecasting* (J. R. Bright and M. E. F. Schoeman, eds.), Prentice Hall, Englewood Cliffs, New Jersey, 1973, pp. 276-290.

2. Conceptual framework for technology monitoring

Technology monitoring is practised as a support function in some corporations and as part of a business-environment scanning procedure for supporting strategic planning in other corporations. Technology scanning and monitoring help in clarifying future action and in evolving strategic options, as shown in figure 7. It has been found that many organizations do not have institutional arrangements for processing and utilizing information regarding general trends in technology.

The starting point for technology monitoring is core competence. Core competence is the basis of competitiveness [1]; it describes a series of critical capabilities that is unique, superior in nature, lasting and capable of differentiating the firm from others.

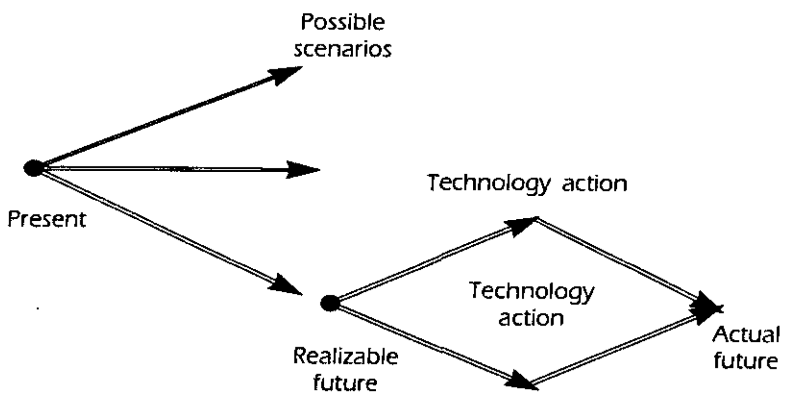
Monitoring helps in sustaining core competence by understanding its dynamics. Two dimensions relevant to monitoring are:

- ❑ The exploration dimension: vital for analysis of the techno-commercial trends and potential future trajectories
- ❑ The normative dimension: for sharpening the focus or directed vision of a specific product, technology or business

> Monitoring helps in answering a series of questions such as:
>
> What are the trends in technology?
> What are the emerging opportunities in technology?
> What actions are to be initiated?
> How do the various technological alternatives compare?

The application of technology monitoring enlarges the scanning base so that various technology ideas are examined through an evaluative procedure. Based on this, choice among the various options can be narrowed down and the business focus can therefore be sharpened.

Figure 14. Monitoring focus



Schematically, scanning and monitoring helps in optimizing present action and planning for the future by clarifying future technology trajectories and designing strategies for realizing identified futures. This is schematically shown in figure 14 above.

Monitoring attempts to link the realizable future and the action imperatives that are needed in the present. This helps in meeting the challenges of a future reality by anticipating opportunities as well as threats through a single framework.

Monitoring at various levels

The focus of technology monitoring will differ depending on the level at which it is being conducted [2]. The levels involved are:

- The enterprise level
- The national level
- The global regional level

The outline of a technology monitoring system [1] is given in figure 15 below.

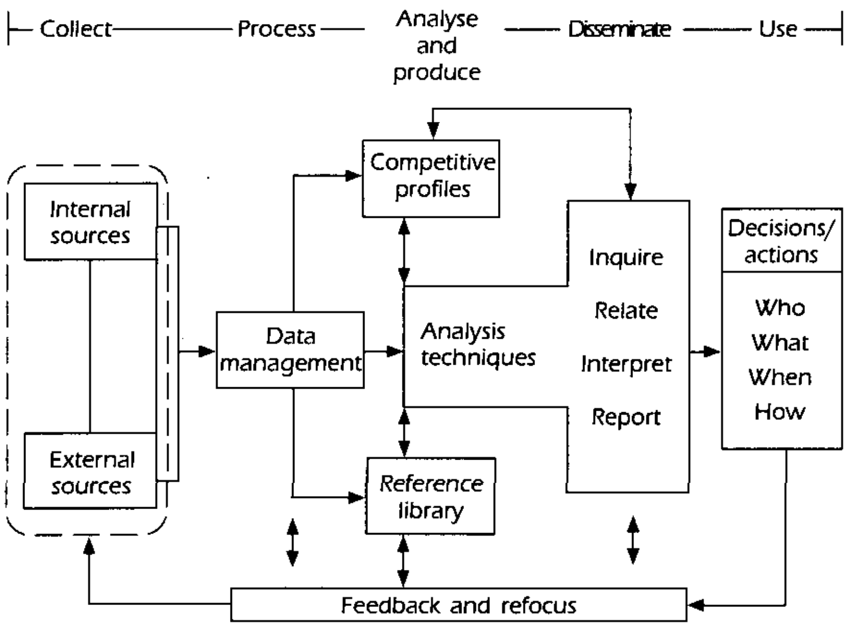
Enterprise level

At the enterprise level, technology scanning and monitoring are used for sharpening strategic focus and evaluating technology trends. At this level, the objectives of monitoring are to identify new product ideas for licensed production or commercialization and to start new business ventures.

The use of technology monitoring will depend on the size of the firm as well as the product vintage. A small firm may be looking for a new product idea or a licensing partner. A medium-sized enterprise may be searching for technological opportunities in order to grow or diversify. A large firm may use monitoring for identifying:

- An alliance partner
- Ideas for diversification
- Smaller firms for licensing their production technology
- Partners for developing new markets or
- A sourcing agent for a multinational corporation

Figure 15. A technology monitoring system



Alternatively, monitoring may be used to initiate an R & D project for realizing a new business opportunity or to gauge technological trends in a given field.

Monitoring objectives at enterprise level depend on:

- The purpose of monitoring
- The type of business objectives envisaged after monitoring
- The proprietary nature of the technology involved

If the technology to be acquired is of a proprietary nature, then monitoring other sources may not yield results. Direct contact or patent search can be of use in all cases where the technology involved is tightly held by the technology supplier. The objectives for which monitoring can be used are given in table 3. As indicated earlier, the objectives of technology monitoring and forecasting are closely related. Table 3 deals with the time dimensions of monitoring for various types of enterprises.

The actual application of the results of monitoring can differ from firm to firm and will depend on competitive positioning. If a firm is looking for a new product for commercialization through licensing, then scanning is an end in itself. However, if scanning is used for preparing long-term action imperatives, scanning may lead to action with regard to technological options.

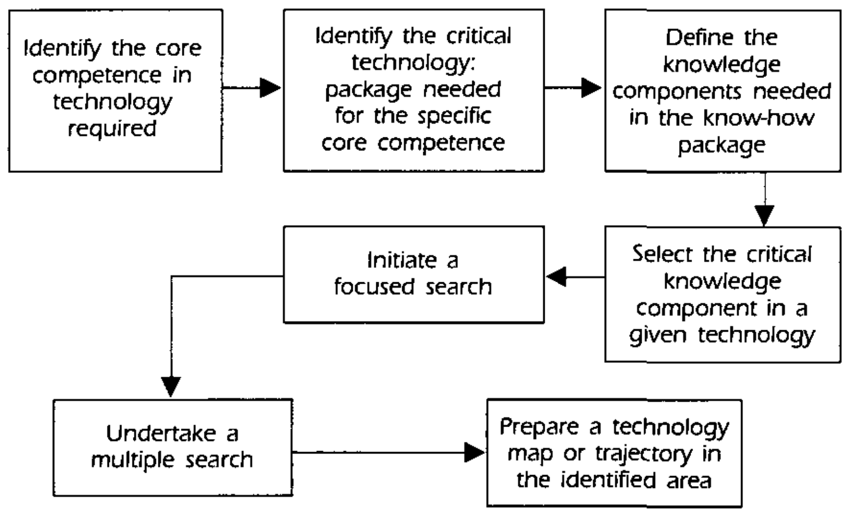
A typical technology monitoring exercise will involve the following actions at the user end in the enterprise [3]. The sequence is schematically given in figure 16 below.

1. *Identification of areas of technology*: identifying core competencies in technology that can be useful for a variety of applications in different markets.

Table 3. Technology monitoring objectives

Type of firms	*Monitoring*	*Forecasting*	*Assessing*
Small enterprise in a low-technology field	Emerging technologies with growth potential	Technology alliances for developing future strategic options	New manufacturing options: potential technology modernization schemes
Small enterprise in a high-technology field	Identification of growth technologies	Areas for new ventures: forming alliances with R & D agencies in order to exploit new technologies	Assessment of new investment options and possible linkages with large or global players
Medium-sized enterprise	Technologies for diversification and alliance-making	Identification and implementation of investment plans and joint ventures	Technology upgrading options
Large enterprise with a comparatively static technology	New manufacturing improvements	Technologies for diversification and alliance options	Technology modernization options
Large enterprise in a high-technology area	New product ideas and diversification	Technological alliances and long-term capability building	Assessment of future options
Large enterprise with substantial global presence	New ideas and global search	Core competence renewal on a continuous basis	Continuous assessment of new opportunities for investment and diversification

Figure 16. Sequence of technology monitoring



2. *Identification of critical technology packages*: the identified areas of technology are translated into know-how packages by dividing the former into component technologies that need to be monitored. For example, if a firm's lighting technology is to be monitored, the firm's major know-how package also needs to be identified. At this level, various options, demand patterns and competitive elements (nature of competitors) are monitored.

3. *Defining knowledge components needed in the know-how package*: for example, in lighting technology, the package (fluorescent lamps) is examined and the technology element needed is identified. Analysing options and monitoring trends show that fluorescent lamps will continue as a lighting source.

4. *Selecting critical knowledge components in the given technology*: for example, the technology used to make compact fluorescent tubes seems to be a promising candidate for technology transfer.

5. *Initiating a focused search*: identifying manufacturers, the range of technical characteristics needed, such as existing patents, and sending queries as well as initiating preliminary discussions with industry experts and consultants.

6. *Undertaking a multiple search*: this involves identification of the following:

   - ❑ Internal capabilities
   - ❑ Potential suppliers

- Potential collaborators
- Potential manufacturing options
- Cost implications
- Quality and standardization
- Marketing requirements
- Investment options

7. *Preparing a technology trajectory in the identified area*: this part of technology monitoring is the component carried out at the user end. It becomes the technology decision support system in the organizational context.

It is comparatively easy to implement a system at enterprise level because of the clarity of objectives and focus on utility.

National level

Technology monitoring at the national level will need to cater to the requirements of many enterprises as well as many decision makers from various ministries or departments. The national level of technology monitoring needs to address a wide variety of objectives, namely:

- To fulfil the monitoring needs of various enterprises
- To support the technology monitoring requirements of various user ministries
- To provide information on potential growth areas so that national planners can prepare long-term technology plans and long-term research projects
- To sensitize decision makers to creating a strategic vision and to laying the foundation for long-term thinking

In other words, technology monitoring at the national level needs to cater to three distinct user segments, namely:

- National-level decision makers focusing on technology
- National-level decision makers from ministries who are the users of technology (such as industry, telecommunications, power, agro-processing and rural development)
- Enterprise-level decision makers

Only selected countries have attempted such a comprehensive technology monitoring system. Country-specific technology monitoring efforts are needed because the normative requirements, strategic requirements, resource endowments and industry structure differ considerably among countries. National-level monitoring helps to support such specific requirements. For example, Madagascar is examining its marine technology requirements and marine resource utilization technologies in its technology monitoring efforts. Japan and the Republic of Korea both have government-mediated technology monitoring systems. In the case of Japan, this operates at three levels. The methodology is discussed in annex II. At the Science and Technology Agency level, information scanning is done across broad areas. The focus of monitoring in this case is policy-oriented. The information is used to guide monitoring done at the Ministry of International Trade and Industry for various user industries. The focus of monitoring in this case is the acquisition of strategic information. The Institute of Future Technology prepares long-term forecasts based on such information. The focus of monitoring in this case is awareness creation. Most developing countries do not have such a well-orchestrated system in which monitoring is carried out at various levels. Developing countries are at varying levels of industrial development. The industry structure and export structure differ considerably. National-level monitoring efforts need to support those specific requirements.

Global regional level

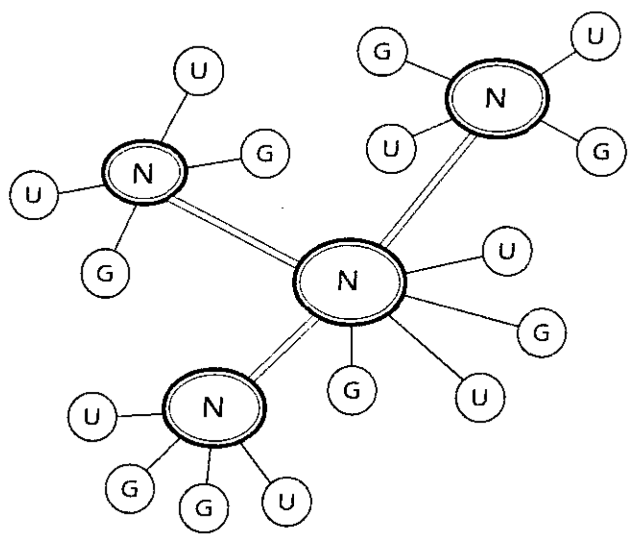
To avoid duplication of the collection of technology information and monitoring, a global regional level monitoring system can be used. Ideally, a number of countries develop and implement a system jointly, the results of which are of benefit to participating countries. Two such systems are currently in operation.

One system operates in Latin America and another encompasses Asia and the Pacific region. Both systems focus on selected areas of technology and address the needs of selected end users. As mentioned earlier, technology monitoring facilitates:

- ❑ Selecting technologies by improving the database for decision-making
- ❑ Understanding the trajectory of significant technologies ahead of time so that advance action can be initiated on new technologies or commercialization of new technologies
- ❑ Identifying potential sources from which technologies can be obtained or alliances formed for technology transfer

The main reason for the current interest in technology monitoring is that firms are pooling efforts on the subject. Technology monitoring is a precompetitive activity. After monitoring, the specific application of the results of monitoring will depend on the specific mission of the organization and its core competence. The application of technology monitoring is organization-specific. Technology monitoring at the regional level can help in creating a win-win situation for all the partners since it improves the decision-making base for the choice of technology and facilitates technological transfer through an improved information exchange. It also helps in sharing the monitoring cost and in pooling the resources for carrying out technology monitoring. This is a multi-faceted network. It facilitates both collection through coverage of a large number of sources and exchange of monitored information to a large number of locations and users, as shown schematically in figure 17 below.

Figure 17. A global regional monitoring network



Key: N = national node; U = user; G = generator of information.

The figure above shows a global regional hub connecting to different hubs that will ensure more users benefit and more sources are covered. There is only a marginal increase in the organizational expenses for the collection of information, while dissemination covers a larger base. It is essential to ensure that both hubs have common data formats and compatible interfacing systems. Technology monitoring helps in reaping entrepreneurial or Schumpetrian rents through:

- Improved risk management through sharing risks and knowledge
- Better entrepreneurial insight by providing a wider information base
- A larger number of technological options to select from
- Increased channels for information dissemination

Information exchange allows better quality decisions to be made. Exchanges among various geographic regions lead to a rapid diffusion of new information. Conducting technology monitoring collectively in a number of countries through the coordinating efforts of UNIDO can help in the creation of a broad base for the exchange of information and better cooperation among firms participating in the network. A global regional level technology monitoring system can mean an increase in:

- Sourcing for components
- Technology transfers
- Formation of alliances (marketing, manufacturing and design)
- Licensing of technologies
- Trade
- Technical cooperation

Transnational companies are increasingly outsourcing products from developing countries. Monitoring can therefore assist in increasing information dissemination on outsourcing opportunities available to developing countries. Firstly, this will enable firms from developing countries to become integrated with global industrial systems. Secondly, many ideas originating from developing countries can be developed through cooperative efforts. Monitoring can help in the evolution of joint development projects, joint ventures and joint market development. Strategic alliances are emerging as a viable alternative in which risks are shared and resources are pooled. Thirdly, there is tremendous scope for cooperation among firms from developing countries. Technology cooperation could be enhanced with an increased exchange of information about potential technocommercial transactions. Technology monitoring carried out as a joint initiative has a number of advantages, including the following:

- Monitoring and cost of collection through pooling is lowered
- Duplication of efforts is avoided by sharing the information
- A large information base is provided, covering many countries and many ideas

- The range of technology options for firms is improved by widening the scope
- Negotiating ability is improved through better option-analysis
- Entrepreneurship is stimulated through increased use of innovations

Global regional technology monitoring can create a win-win situation for corporate decision makers as well as national decision makers. However, the focus of monitoring efforts is likely to be different at all levels. It is necessary to know the user profile before designing the appropriate technology monitoring system.

Relevance of monitoring for developing countries

Technology monitoring can help developing countries to grow rapidly in a number of ways, as discussed below.

High potential for improvement: Developing countries are mostly in the early stages of industrial development. The potential for technology upgrading, productivity improvement and efficiency improvement is much higher in these countries. By benchmarking technology levels, it may be possible to identify potential areas for catching up. For example, the amount of coke used in steel making in Japan has been around 490 kilograms per ton of hot metal, whereas steel-making firms in India use between 700 and 1,100 kilograms. This shows that there is tremendous potential for reducing the amount of coke used. Monitoring efforts need to focus on identifying the following options:

- Improving the skills of operators in order to reduce the amount of coke per ton of hot metal
- Upgrading the furnaces and coke ovens through technological transfer
- Changing the process operations and improving instrumentation
- Installing better process monitoring, measurement and control systems
- Improving raw material preparation and inputs

Initiating a gap analysis of various technology operations and improving technologies are more critical for developing countries. The potential for improvement is higher in the case of developing countries because they tend to be in a lower part of the learning curve with regard to a number of areas of technology.

Industrial consultancy in its infancy: In the case of developed countries, industrial consultancy is well institutionalized. Battelle Memorial Institute, Arthur D. Little, Inc., KPMG, Stanford Research Institute, Electrical Power Research Institute and McKinsey & Company are experienced in technology monitoring as well as forecasting. Those firms have accumulated experience and comprehensive data support. Developing countries are in the infancy phase of industrial consultancy, thus technology monitoring efforts can improve the quality of industrial consultancy. Consultants have a major role in acting as intermediaries, and an institutionalized monitoring system will assist in its rapid diffusion in developing countries as well as stimulate the consultancy culture. Such learning will have a multiplier effect.

Some of the needs are country-specific: Some of the technology information requirements of developing countries are country-specific. Codification and collection of specific country experiences and capabilities need to be done in a normative context taking into consideration factors such as:

- The country's requirements
- Nature of resource endowments
- Industry structure and mix
- Skill availability
- Level of development
- Composition of imports and exports

Technology monitoring at the national level can capture the unique features and requirements of each country. Industrial crafts and handicrafts are also country-specific. Monitoring and dissemination of information on country-specific products and concomitant skills can lead to the support of traditional practices through dissemination of information and facilitation of trade that may be a consequence of technology monitoring. Monitoring trends in technology helps in the integration of local markets and products with the global system.

Global marketing opportunities: Monitoring at both the national and regional levels will help developing countries to disseminate information on potential technologies and products to global as well as emerging markets. The emergence of the Internet and the World Wide Web provides considerable opportunities for developing countries to become integrated into the global economy. Without the collection of information on technology opportunities, scanning and monitoring efforts, such opportunities cannot be fully realized. Technology monitoring efforts at the enterprise level improve collection, dissemination and analysis of information prior to decision-making.

The above indicates that developing countries need to mount special efforts to become integrated into the global economy. Technology monitoring can facilitate this process. Monitoring can help in stimulating entrepreneurial activity through:

- Joint research efforts
- Cross-border licensing of technologies
- The formation of joint ventures

Developing and implementing technology monitoring activities at the enterprise, national and global regional levels will improve the decision-making base as well as technology negotiations through effective decision support tools. Technology monitoring can be used for various strategic purposes in an organization. These are summarized schematically in figure 18.

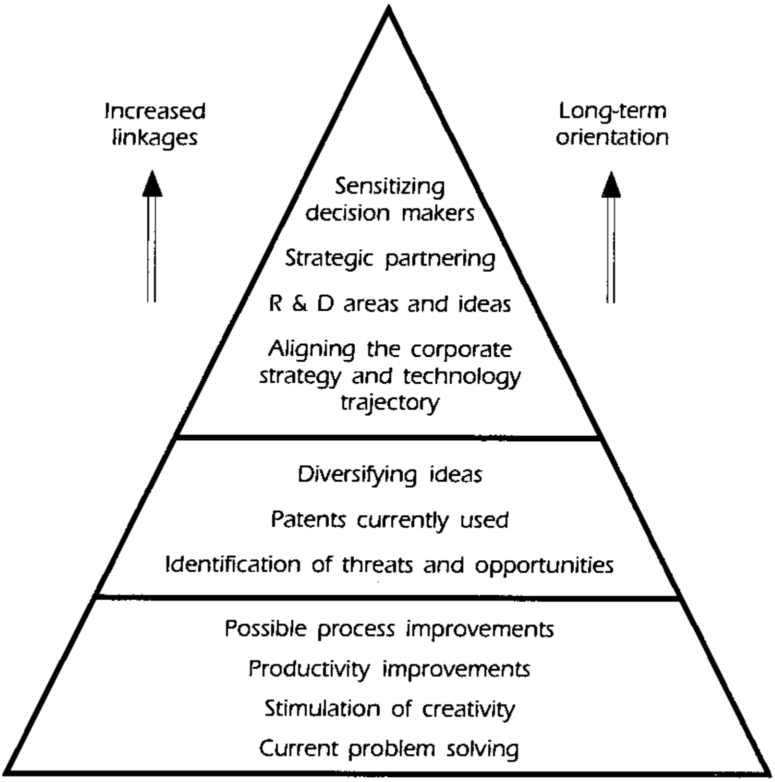
Technology monitoring improves the selection of optional technologies, the detection of new opportunities and focuses managerial attention [4] by strengthening the surveillance filter, attitude filter and power filter, as shown in figure 19.

Entrepreneurship development: Technology monitoring and dissemination of results will facilitate entrepreneurship development. Small and medium-size enterprises need access to information on:

- New market opportunities
- New product ideas
- New patent information
- New manufacturing technologies
- Sources of technology and equipment

Technology monitoring can facilitate the development of entrepreneurs by encouraging people to be informed about the emerging trends in technology and emerging business opportunities. Both technology innovation and technology diffusion will become active if more people are made aware of new technological trends as well as opportunities. Acceptance of technological change will become easier when there is a greater degree of awareness. Thus, monitoring triggers a search for and an acceptance of new ideas. Furthermore, monitoring encourages people to learn new skills and competencies so as to overcome technological obsolescence—and makes less arduous the transition from the current generation of technologies to the next.

Figure 18. Technology monitoring at various levels of the organization

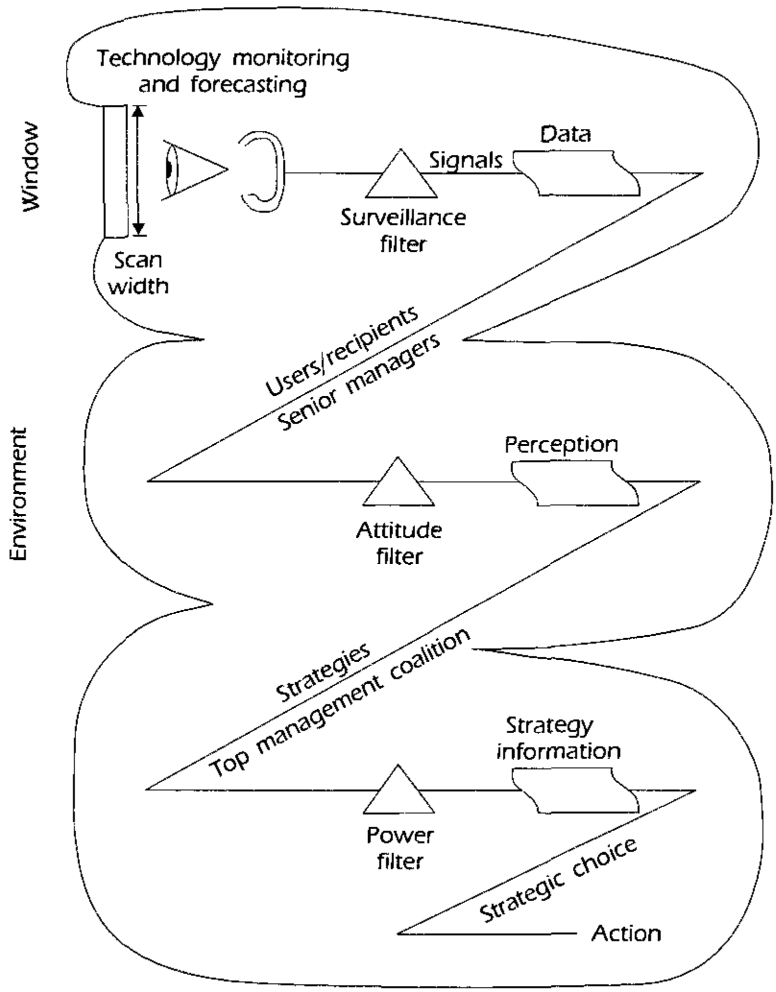


Creating an environment conducive to innovation: Developing countries tend to be dependent on technology imported from other sources. Unless there is an environment conducive to innovation, both the stimulation of innovation as well as its diffusion will be slow. Technology monitoring helps to ensure that an environment is conducive to innovation by sharpening all three perception filters, namely:

- The surveillance filter
- The mentality filter
- The power filter, shown in figure 19

Perception is a crucial trigger for innovation. Technology monitoring can make people perceive technological change as an opportunity rather than as a threat. Innovation will be perceived a desirable course in the competitive context of responding to change. Technology monitoring will facilitate both stimulation of innovation as well as the acceptance of new innovations in developing countries.

Figure 19. Technology awareness in the organization



References

1. D. Bernhardt, *Perfectly Legal Competitor Intelligence: How to Get it, Use it, and Profit from it*, Pitman, London, 1993.
2. B. Bowonder, "Technology Monitoring at the Enterprise Level", Meeting on Cooperation in Technology Monitoring in Developing Countries, November 1994, New Delhi, pp. 22-25.
3. S. Barabaschi, "Managing the Growth of Technical Information", *Technology and the Wealth of Nations* (N. Rosenberg, R. Landau and D. C. Mowery, eds.), Stanford University Press, Stanford, 1992, pp. 407-434.
4. D. Brownlie, "Environmental Analysis", *Companion Encyclopedia of Marketing* (M. J. Baker, ed.), Routledge, London, 1995.

3. Technology monitoring methodology

The present chapter describes processes and methodologies used in technology monitoring.

Monitoring process

Given the diversity of possible forms of monitoring, any suggested set of steps must be carefully adapted to the specific needs of organizations. The chapter presents a five-step process for technology monitoring. This involves:

- ❑ Determining the monitoring objectives and focus
- ❑ Defining the technology and mapping the context
- ❑ Devising a monitoring strategy
- ❑ Analysing and interpreting the information
- ❑ Managing and communicating the results

The steps involved in technology monitoring are the focus of the following discussion; the steps are also presented in table 4 and figure 20 below.

Determining monitoring objectives

As with most complex systems, the monitoring process can be made more transparent by dividing it into subcomponents, as shown in figure 21 below.

Each of the dimensions represents a focus across which scanning and monitoring should be carried out [1]. The purpose of determining the monitoring objectives is to increase the probability that signals of technology change and opportunities are accurately observed and successfully decoded.

Operational dimension

The operational dimension of the firm or organization relates to the design, engineering and manufacturing process that generates a product. It involves the following:

Table 4. Steps in technology monitoring

Steps	*Activities*
Determining the monitoring objectives and focus	Analysing dimension: - operational - competitive - stakeholder - social/environmental - technological
Defining the technology and mapping the context	Defining the technology Mapping the context Comprehensive scanning and searching for ideas
Devising a monitoring strategy	Sharpening the focus Setting the monitoring boundary Defining the monitoring format
Analysing and interpreting the information	Mapping technological trends Detailed analysis
Communicating the results	Managing and communicating the results Sensitizing users Selling the concepts within the organization Integrating the results of monitoring with the overall organizational action

Figure 20. Steps in technology monitoring

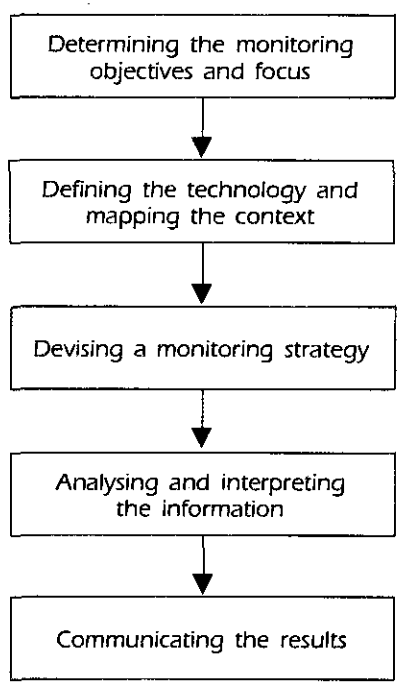
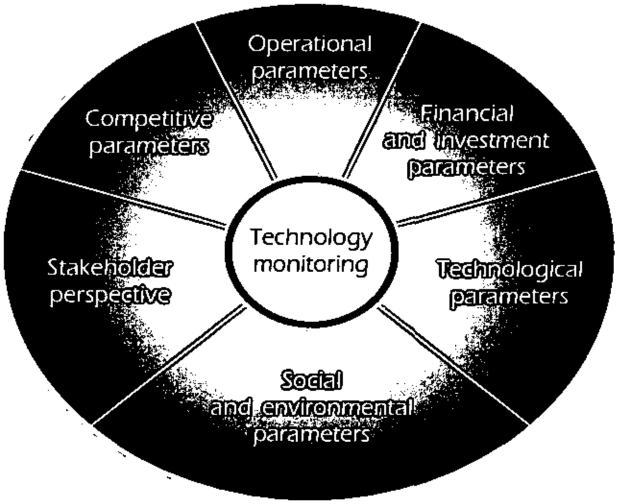


Figure 21. Dimensions of technology monitoring



- ❑ Economics of production
- ❑ Production capacity
- ❑ Resource availability
- ❑ Component availability
- ❑ Productivity
- ❑ Conversion efficiency
- ❑ Input requirements
- ❑ Quality cost trade-offs

If the product is already available, these can be easily obtained. The objective of monitoring is to identify critical success factors.

Competitive *dimension*

The competitive dimension involves deciding whether monitoring competitive elements can yield either a new idea, a new concept, a new application, a new product or a new production process. Products and markets are at the heart of it. The focus will be on conducting a competitor analysis. It will help in the diagnosis of:

- ❑ Likely future goals of competitors
- ❑ Current strategy of competitors

- Assumptions made by competitors
- Capabilities of competitors

Xerox Corp. of the United States has perfected competitive analysis and converted it into competitive benchmarking [2]. Learning from the intents and actions of competitors and crafting a procedure for moving ahead of competitors are two essential elements of competitiveness. This is more of an intuitive and experiential process and monitoring may provide important information about this.

Stakeholder dimension

The interest and attitudes of the various stakeholders in an organization can have an important impact on the firm's success in financing, producing, distributing and selling its products or services [1]. Scanning and monitoring the stakeholder dimension involves analysing the long-term trends and hypothesizing about future events that could emerge from the social systems they represent. Subdividing the influences into various dimensions increases the probability that signals in the environment are not missed amidst noisy signals.

Social and environmental dimension

Two major aspects that can influence the technology trajectory are social and environmental awareness. Demographic and socio-economic trends can move technology in different directions. For example, environmental awareness facilitates the growth of products such as:

- Biopesticides
- Natural colours from plants
- Plant-based flavours
- Environmentally friendly dyes
- Biodegradable polymers
- Reusable packaging
- Organic farming products

In monitoring exercises, life-cycle analysis and life-cycle cost estimates are becoming critical. The costs of reusing or recycling need to be assessed as an integral part of the life cycle. Life-cycle cost assessment has become an acceptable tool for understanding long-term acceptance. As environmental regulations become stringent, the availability of eco-friendly products is likely to increase. Monitoring helps in understanding long-term implications through the evaluation of signals and trends.

Technological dimension

Changes in technology influence markets, products, services and the structure of industry. Five major trends have made technology a major driving force of change, namely:

- Convergence of computing, telecommunications and entertainment
- Tightening of intellectual property rights
- Rapid product obsolescence
- Intensive R & D
- Increased formation of strategic alliances

Technology influences business in two ways: it facilitates breakthroughs that may revolutionize products, processes and markets, bringing the potential for sustainability and for sustainable competitive advantage, and it helps in providing a sustainable early lead to successful developers.

Enterprises not actively pursuing R & D at the cutting edge of scientific and technological knowledge can benefit from development by others [1]. Comprehensive monitoring activities can help prepare the alert observer to become:

- An early competitor
- A subcontractor
- A supplier
- A licensee for the commercialization of new developments in technology

The emergence of design firms and engineering firms can help in realizing product ideas rapidly, thereby reducing the idea-to-customer cycle. Rapid changes in technology have made it necessary to exploit new ideas quickly since product life cycles have become shorter.

Financial and investment dimension

Availability of financing and willingness of the financial market to provide capital have been major determinants of corporate change. Financial markets have undergone change. The financial dimension is intertwined with the competitive dimension. In any business, the financial dimension affects the profitability, form and risk of temporary investments. The perception and support of financial institutions and venture funds are crucial for commercial exploitation of new technology. Though many attractive technologies are invented in many parts of the world, only a fraction of them go through the complete innovation chain sequence to reach the customer. Financial aspects, investment requirements and risk will be a major input for monitoring. The risk components are:

- Operational
- Commercial
- Technological
- Environmental
- Foreign exchange
- Political

Analysis of risk provides useful insights for the monitoring group into long-term potential, threats and opportunities.

Defining the technology and mapping the context

Technology mapping is a practical aid for carrying out an in-depth analysis of the detailed technology trajectory. A technology map is a time-based trajectory of technology change that can help decision makers to exercise judgement regarding a potential technological development [3]. By understanding the likely shifts in the bases of competition due to technology and the time-frames in which these shifts might occur, implications for strategic action can be ascertained. The basic objective of technology mapping is the creation of competitive advantages through the analysis of strategic options in the light of expected technological development or new product introduction. Defining the boundaries of the technology will facilitate the monitoring process.

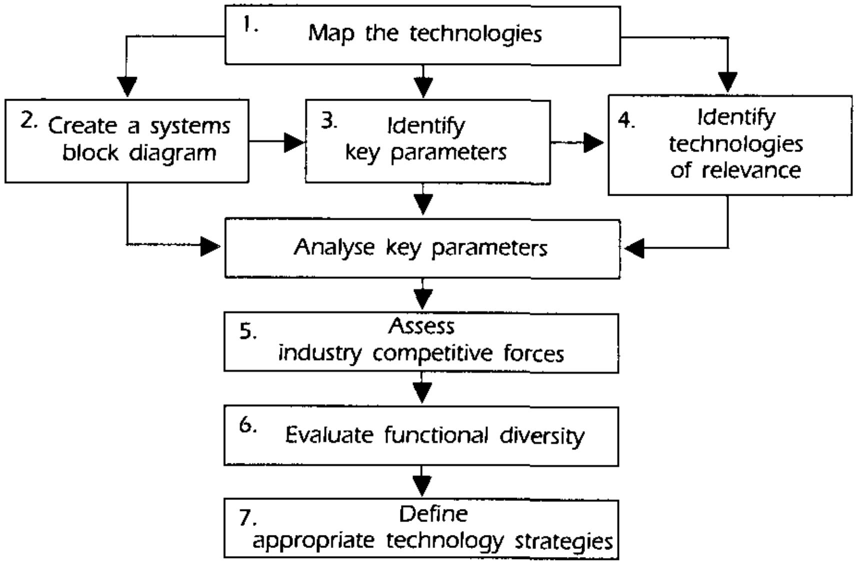
To create a technology map, it is necessary to trace the technology evolution trajectory. After examining the origin of the trajectory, a key parameter analysis is conducted. Such an analysis consists of the following three steps:

- Analysing the product line in terms of the various subsystem elements of the design
- Identifying key parameters in each of the subsystems
- Identifying technologies that potentially affect the parameters identified

The process of technology mapping is presented in figure 22 below.

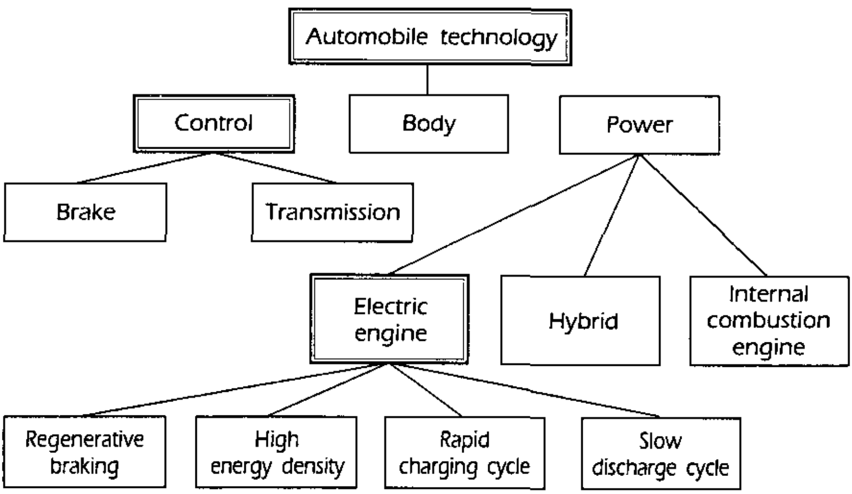
An example of the technology mapping process is given in figure 23 below.

Figure 22. The seven steps of technology mapping



Source: R. A. Goodman and M. W. Lawless, *Technology and Strategy*, Oxford University Press, New York, 1994.

Figure 23. Automobile technology mapping



The above illustration highlights the process, discussed in more detail below.

Identifying the key product technology

This involves creating a relevance tree for relevant technology. If automobile technology is identified as the key technology and a relevance tree is prepared as shown in figure 23, it becomes clear that power systems become the core competence needed for competitive advantage. It can be seen that evolving technologies include hybrid vehicles and improved, battery-operated electric cars. From the current R & D efforts shown in table 5, it is clear that electric vehicles are likely to be the major candidate in technology to be monitored. In the case of existing automobiles (internal combustion engines), R & D efforts are moving in the direction of improved fuel efficiency.

Identifying key parameters

Emerging options relative to electric vehicles are evaluated using the following parameters:

- ❑ Low degree of pollution
- ❑ Higher fuel efficiency
- ❑ Lower weight
- ❑ Energy density
- ❑ Duration of charging cycle
- ❑ Environmental friendliness
- ❑ Maintenance intensiveness
- ❑ Life-cycle cost

Identifying technologies

Comprehensive monitoring of the following technologies are carried out:

- ❑ Fuel cells
- ❑ New batteries
- ❑ Improvements in the internal combustion engine
- ❑ Hydrogen combustion engine
- ❑ Flywheel drive

Monitoring shows that maximum research thrust is in areas such as fuel cell, new batteries and hydrogen combustion. An analysis of the current battery technology for electric vehicles [4] is presented in table 5 below.

Table 5. Technology status of current batteries

	Mid-term	Long-term	*Present* status
Specific power (W/kg)	150	400	
Lead-acid			67-138
Nickel-iron			70-132
Nickel-cadmium			100-200
Nickel-metal hydride			200
Sodium sulphur			90-130
Sodium nickel chloride			150
Lithium polymer			100
Energy density (Wh/L)	135	300	
Lead-acid			50-82
Nickel-iron			60-115
Nickel-cadmium			60-115
Nickel-metal hydride			152-215
Sodium sulphur			76-120
Sodium nickel chloride			160
Lithium polymer			100-120
Specific power (Wh/kg)	80	200	
Lead-acid			18-56
Nickel-iron			39-70
Nickel-cadmium			33-70
Nickel-metal hydride			54-80
Sodium sulphur			80-140
Sodium nickel chloride			100
Lithium polymer			150
Life (years)	5	10	
Lead-acid			2-3
Nickel-iron			
Nickel-cadmium			
Nickel-metal hydride			10
Sodium sulphur			
Sodium nickel chloride			5
Lithium polymer			
Cycle life (80% DOD)	600	1 000	
Lead-acid			450-1 000
Nickel-iron			440-2 000
Nickel-cadmium			1 500-2 000
Nickel-metal hydride			1 000
Sodium sulphur			250-600
Sodium nickel chloride			600
Lithium polymer			300
Ultimate cost ($/kWh)	< 150	< 100	
Lead-acid			70-100
Nickel-iron			160-300
Nickel-cadmium			300
Nickel-metal hydride			200
Sodium sulphur			100+
Sodium nickel chloride			< 350
Lithium polymer			500

Source: J. J. MacKenzie, The Keys to the Car: Electric and Hydrogen Vehicles for the 21st Century, World Resources Institute, Baltimore, 1994.

After the preliminary detailed monitoring is done, an enterprise-specific analysis takes place, determined by:

- Competence
- Investment needs
- Strategic intent
- R & D infrastructure
- Marketing focus

For example, firms from developing countries may not opt for the development of technology. They may acquire technology, form a joint venture or create a marketing alliance for distribution or develop an after-sales network through an alliance.

Devising a monitoring strategy

To be successful in the long run, a monitoring strategy must yield benefits that exceed the monitoring cost through its contribution to maximizing the risk-adjusted net present value for the organization [3]. The level of investment in monitoring and the choice of monitoring activities are elements of managerial judgement that, because of their impact on firm value, have a direct strategic bearing. The following are elements of a monitoring strategy.

Sharpening the focus of decision support: This step is based on the preliminary search to identify the technological elements that give the most effective entry into the market. The objective of this step is to define critical success factors. The variables that help by requiring least cost and most effective intervention are the criteria for success factors. The monitoring strategy needs to sharpen the options through strengthening the decision support system. The decision support system is established through identification of strategic critical success factors. Critical success factors can be identified by considering three elements:

- Technology that provides substitute product possibilities. This could affect market growth and new production methods that reduce the cost structure;
- Interventions identified and/or changes using the existing core competencies. These could affect new product options;
- Customer preference that can substantially influence the product or service dimension.

These need to be identified through a participative process and through a cross-functional group to eliminate functional biases or existing product biases. A brainstorming exercise with top management involvement would be an appropriate way to identify the above-mentioned.

Having sharpened the focus on technology, product trajectory and customer preferences, the next major step will be to conduct the boundary-setting exercise for technology monitoring.

Setting the monitoring boundary: The monitoring boundary should be defined before designing the information collection format. Three aspects that determine the boundary of the monitoring exercise are time-frame, geographic focus and feasibility of a product, technology or process.

The first question addresses whether the event in question is a feasible one. In assessing the feasibility, both probability and impact need to be assessed. If both the probability of the event occurring and the impact on the business are low, then it is not a worthwhile option. The future context of any organization is made up of elements emerging from the probable environment, the possible environment and the improbable environment.

Monitoring strategy should seek to identify high pay-off events from the range of probable and possible events. Determining the feasible boundary is the outcome of this step. In practice, it can be observed that the relative importance of business information [5] differs considerably, as shown in box 2 below. The various sources of information an organization should scan are presented in table 6.

Table 6. Sources of information on the business

Location	*Types*	*Sources of information on the business environment*
Inside the company	Written	Internal reports and memos, planning documents, market research, management information service/system.
	Verbal	Researchers, sales force, marketing, purchasing, advisers, planners, board.
	Combination	Formal and informal meetings, e.g. working parties, advisory committees.
Outside the company	Written	Annual reports, investment reports, trade association publications, institute yearbooks, textbooks, scientific journals, professional journals, technical magazines, unpublished reports, government reports, unpublished papers, abstracts, newspapers, espionage.
	Verbal	Consultants, librarians, government, officials, consumers, suppliers, distributors, competitors, academics, market researchers, industry bodies, journalists, spies, bankers, stockbrokers.
	Combination	Formal and informal meetings, membership of government working parties and advisory boards, industry bodies, trade associations.

Box 2. The relative importance of sources of business information

1. Verbal sources of information are much more important than written sources. As much as 75 per cent of information cited by executives is in verbal form.
2. The higher the executive in the organization, the more important verbal sources become.
3. Of the written sources used, the most important are newspapers (two thirds), then trade publications, followed by internal company reports.
4. The major sources of verbal information are subordinates, then friends in the industry, then superiors (very infrequently).
5. Information received from outside an organization is usually unsolicited.
6. Information received from inside the organization is usually solicited by the executive.
7. Information received from outside tends to have a greater impact on the decision maker than inside information.
8. The outside sources used vary according to the job of the manager, for example, marketing managers talk more to customers.
9. The larger the company, the greater the reliance on inside sources of verbal information.

Source: J. Courtial and A. Sigogneau, "How to Use Scientific and Technological Information to Reveal Strategic Technologies", *International Journal of Technology Management*, vol. 10, No. 1, 1995, pp. 31-44.

The second issue to be examined is time-frame. Uncertainty and time are related, but they should not be equated in developing a monitoring strategy. The recognition of time as an independent range setting encourages the organization to tune the monitoring posture to the apparent rate of fundamental, long-term change. This may depend on the objective of monitoring, size of the organization and the competitive position of the firm.

The third issue to be addressed is geographic focus. For some firms, the focus is multinational whereas for others it is domestic. The boundary-setting process is determined by the organizational objective. The boundary is determined by the need, scope and depth of information required.

The next task is to design the monitoring format that can satisfy the requirements and the identified strategy.

Monitoring format

After setting the boundary, the monitoring strategy needs to be identified. There are five modes of monitoring:

- ❑ Informal observation
- ❑ Conditional observation
- ❑ Informal search
- ❑ Formal search
- ❑ Focused and defined search

These can be broadly grouped into three categories: irregular, periodic and continuous, as shown in table 7. The amount and nature of information obtained through monitoring is dependent on the intensity of the monitoring effort. Obtaining the right kind of information also depends on the sources and how well conditioned the organization is to observe or find it. Formal searches involve relatively high resource demands. They should be undertaken with caution and deliberation, and then only after preliminary and conditional searches. In large organizations, both verbal and non-verbal information needs to be used jointly.

Table 7. A typology of technology monitoring systems

	Irregular	*Periodic*	*Continuous*
Impetus for monitoring	Crisis-initiated	Problem-solving decision-/issue-oriented	Opportunity finding and problem avoidance
Scope of monitoring	Specific events	Selected events	Broad range of environmental systems
Temporal nature	Reactive	Proactive	Proactive
(a) Time-frame for data	Retrospective	Current and retrospective	Current and prospective
(b) Time-frame for decision impact	Current and near-term future	Near-term	Long-term
Types of forecasts	Budget-oriented	Economic and sales-oriented	Marketing, social, legal, regulatory, culture etc.
Media for scanning and forecasting	Ad hoc studies	Periodically updated studies	Structured data collection and processing systems
Organization structure	Ad hoc teams Focus on reduction of perceived certainty	Various staff agencies	Scanning unit, focuses on enhancing, uncertainty-handling, capability
Resource allocation to activity	Not specific (perhaps periodic as fads arise)	Specific and continuous but relatively low	Specific, continuous and relatively substantial
Methodological sophistication	Simplistic data analyses and budgetary projections	Statistical forecasting-oriented	Many "futuristic" forecasting methodologies
"Cultural" orientation	Not integrated into mainstream of activity	Partially integrated as a "stepchild"	Fully integrated as crucial for long-range growth

Source: V. K. Narayan and L. Fahey, "Environmental Analysis for Strategy Formulation", *Strategic Planning Management Handbook* (W. R. King and D. I. Cleland, eds.), Van Nostrand, New York, 1987.

Analysing and interpreting the information

Monitoring involves analysis and interpretation of the selected information. This step converts the search results in terms of organizational context and response. A variety of techniques are used for analysing and interpreting the monitored information.

These are:

- ❑ Mapping techniques
- ❑ Modelling techniques
- ❑ Subjective analysis

The techniques mentioned above are discussed separately in chapter 4.

This step requires industry experts and strategy experts to interact so as to convert monitored information into understandable organizational scenarios.

Managing and communicating the results

Central to the idea of technology monitoring are two difficult concepts:

- ❑ Integrating the results of technology monitoring with the overall organizational action
- ❑ Communicating and selling the concepts within an organization

Any organization needs to find an appropriate method for reporting the results of monitoring to an audience unaccustomed to dealing with ambiguity in information and alternative options. The methodology of technology monitoring needs to be accepted and used as a part of strategic decision-making. This requires the following:

- ❑ Support of top management
- ❑ Integration into current management thinking
- ❑ Harmonizing with the organization's behaviour or culture
- ❑ Sensitization of the users

Aspects to be considered while devising how the results of monitoring will be communicated include:

- ❑ Designing the message
- ❑ Designing the form of delivery
- ❑ Planning the involvement of relevant personnel in the communication process

The focus of the message should be on the decision makers and the implementation process in general. For best results, the process of communication should be participative.

The objective of the five-step methodology is to ensure that the technology monitoring process is institutionalized and is properly dovetailed with the related organizational processes. The communication process to be adopted is discussed in greater detail in chapter 6.

References

1. J. D. Stoffels, *Strategic Issues Management: A Comprehensive Guide to Environmental Scanning*, Pergamon, Oxford, 1994.
2. R. C. Camp, *Benchmarking: The Search for Industry Best Practices that Lead to Superior Performance*, ASQC Quality Press, New York, 1989.
3. R. A. Goodman and M. W. Lawless, *Technology and Strategy: Conceptual Models and Diagnostics*, Oxford University Press, New York, 1994.
4. J. J. MacKenzie, *The Keys to the Car: Electric and Hydrogen Vehicles for the 21st Century*, World Resources Institute, Baltimore, 1994.
5. D. Brownlie, "Environmental Analysis", *Companion Encyclopedia of Marketing* (M. J. Baker, ed.), Routledge, London, 1995, pp. 318-336.

4. Technology monitoring tools

Technology monitoring uses a variety of tools or methods. In fact, to ensure that monitoring results are useful, it is necessary to employ a variety of complementary tools [1-6]. The present chapter examines monitoring tools as well as selected monitoring sources.

Techniques

The techniques used for monitoring can be classified into the following categories:

- Mapping
- Scanning
- Modelling
- Subjective

Mapping

Mapping techniques are used for the purpose of describing the nature, extent or limits of the connection of one variable with another, or with a system of other variables. The simplest mapping technique is the sequential flow chart. The major mapping techniques used for monitoring are:

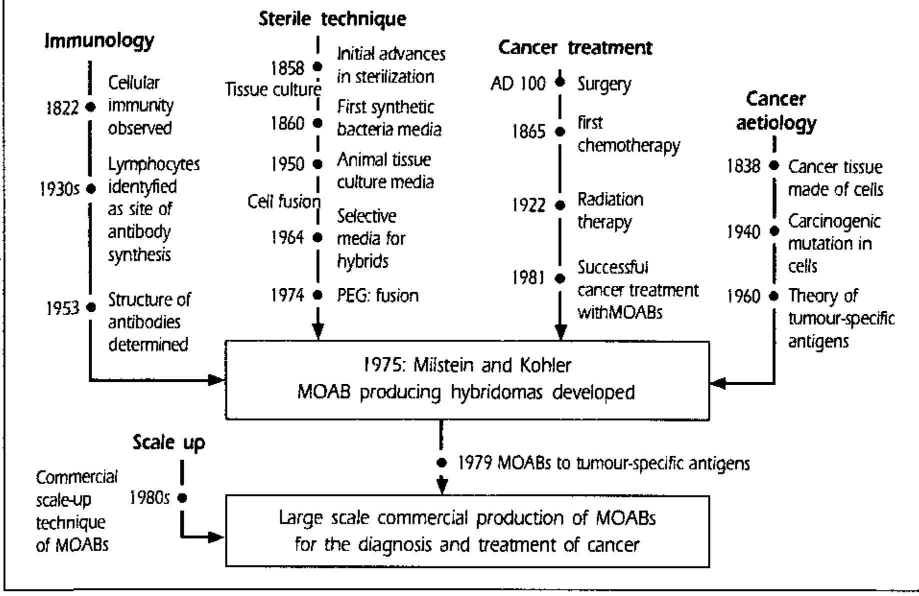
- Contextual mapping
- Relevance tree analysis
- Influence diagram
- Morphological analysis

Contextual mapping

Principle: This method maps the contextual trajectory of a given technology so as to understand the direction of change.

Method: In this method, the trajectory of a technology is mapped using historical growth patterns and technological interconnections among the

Figure 24. Technology map of monoclonal antibodies (MOABs) for cancer treatment



Source: R. A. Goodman and M. W. Lawless, Technology and Strategy, Oxford University Press, Oxford, 1994.

subsystems, by selecting either relevant performance characteristics or functional elements.

Example: The mapping of the use of monoclonal antibodies (MOABs) for cancer treatment is shown in figure 24 above.

The scientific history of monoclonal antibodies has its origin in separate research tracks that include cause, diagnosis, treatment and cure. The map can be divided into five areas of technology, namely:

- ❑ Cancer aetiology
- ❑ Cancer treatment
- ❑ Immunology
- ❑ Tissue culture
- ❑ Manufacturing techniques

The contextual analysis shows that in the medium-term, with few products available, the product life cycle is clearly in the early phase. There are only a few active major players and some innovation-based university projects.

The nature of the market in which small companies operate is highly unpredictable. New technological solutions are offered that either replace older solutions or are solutions to currently unsolved problems. The monitoring exercise indicates that the following are possible and available strategic options:

- Producer preference strategy: a strategy in which a producer concentrates on core competence rather than on market segmentation, since volumes are likely to be low and marketing expenses are likely to be high. Instead of accommodating the customized needs of specific customers, an enterprise that is active in this area needs to focus on product economies;
- Product pioneer strategy: a strategy where the product is placed firstly in the market with an attempt to derive economies of scope through:
  - custom-designed products
  - standardization of component assemblages
  - a combination of modular units able to produce a variety of products.

In the long run, the market will enter the growth phase. Any attempt to enter this phase will mean a higher degree of competition. In the growth phase, niche market strategies will not work. Process innovation strategy, new application strategy or product flexibility strategy needs to be used. In the growth phase, the focus of monitoring should be:

- Competitor strategy analysis
- Market segmentation potential
- Process improvement potential

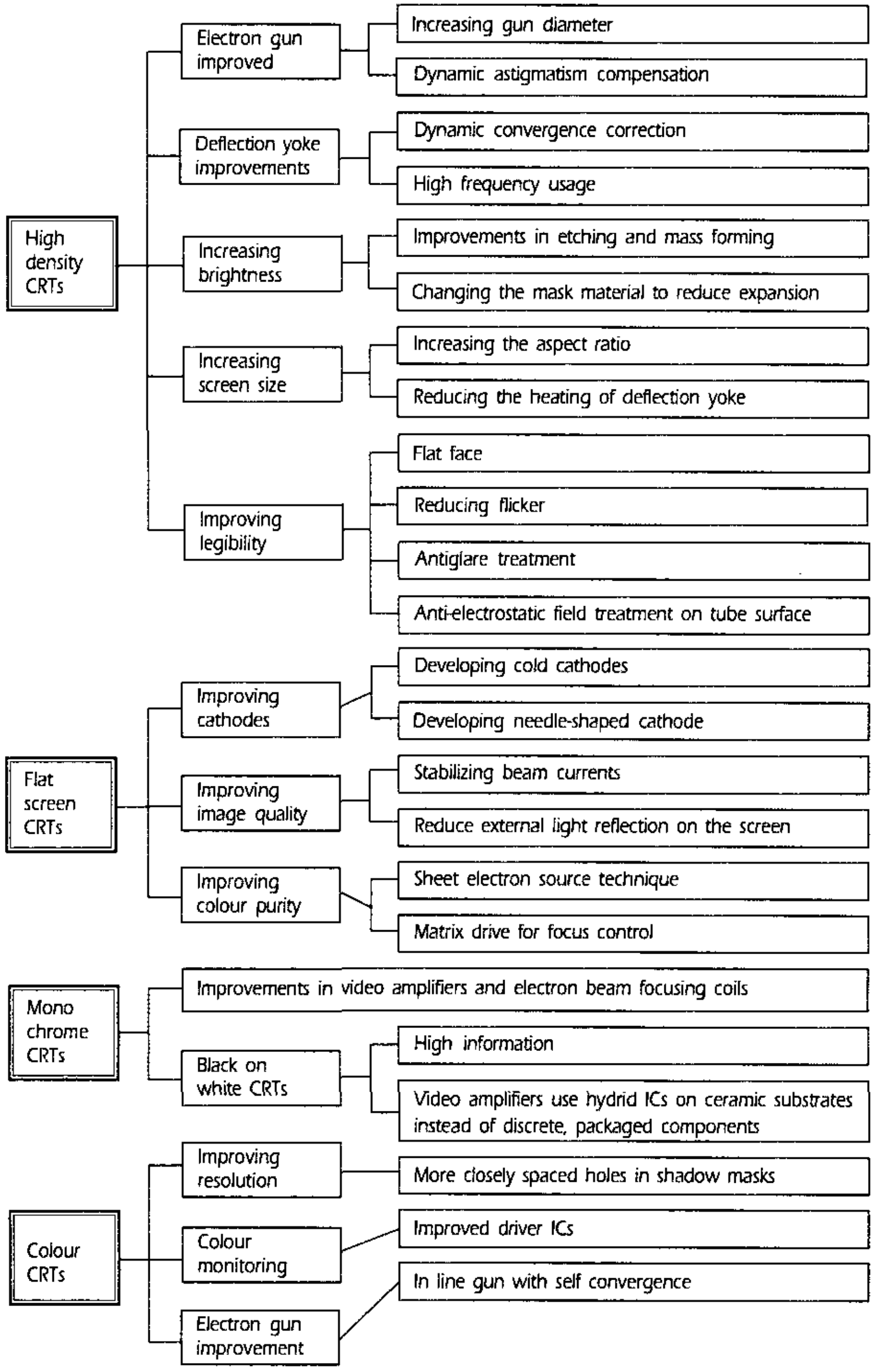
Contextual mapping helps to elucidate the technology trajectory of monoclonal antibodies so as to identify a viable entry strategy for a firm.

Advantages and limitations of contextual mapping: The method gives the overall growth direction but is not capable of analysing possible breakthroughs. Contextual mapping requires a systematic analysis of historical evolution and the combined effort of a number of experts to convert monitoring results into strategic options.

Relevance tree analysis

Principle: Relevance tree analysis is a method of breaking down a product family into various configurations so as to understand new emerging configurations.

Figure 25. Cathode ray tube (CRT) technology trends



Source: B. Bowonder, "Electronic Display Technologies", *Electronic Information & Planning*, 1994, pp. 683-746.

Method: The method involves analysing the hierarchical subsystems of a product family by considering the alternatives for each subsystem.

Example: The emergence of television and computer terminal displays can be monitored using relevance tree analysis. In this analysis, possible changes in subsystems are identified. The relevance tree analysis indicating the likely direction of growth of cathode ray tube technology is presented in figure 25.

The analysis also shows that although cathode ray tube technology is 100 years old, it is continuously evolving to compete with other emerging displays. To understand the dynamics of cathode ray tube technology, the technological changes are viewed in terms of subsystems. Thus, the technological changes in each of the subsystems can be monitored. The five parameters important for a display are:

- Thickness
- Voltage
- Illumination or brightness
- Viewing angle
- Cost

The monitoring exercise indicates that the major directional changes in cathode ray technology can be analysed using a relevance tree as presented in figure 25 above.

The cathode ray display will continue to be the major display for lower-price applications and television applications, as all other displays are in the higher-price segment. Monitoring thus helps in identifying both technology trajectories and potential technological changes.

Advantages and limitations of the relevance tree analysis: The method requires a substantial amount of information on emerging alternatives. A detailed assessment requires the involvement of a number of technology experts. Assessing its potential requires an understanding of user dynamics and of the evolution of the application.

Influence diagram

Principle: Influence diagram is a method of depicting the development of a relationship between input and response.

Method: The input-output relationship is derived in a general fashion by linking relationships operating among the subsystems.

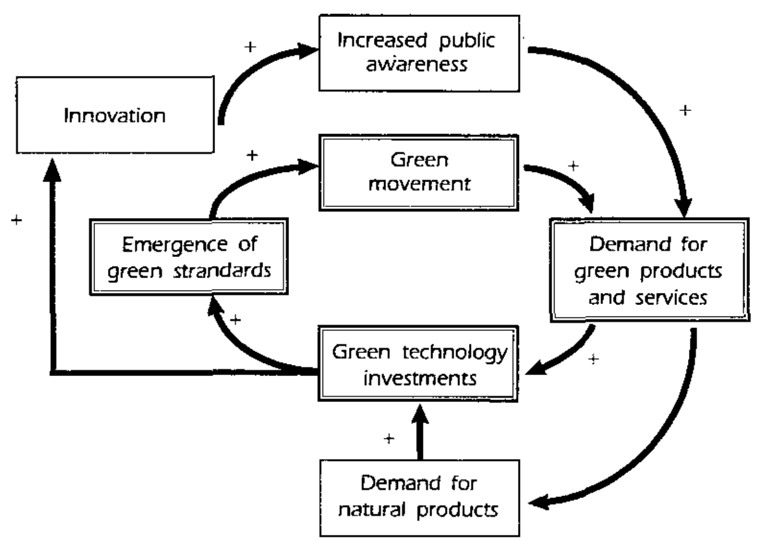
Example: There has been increased support for the Green movement.

The influence of this on technology can be depicted as an influence diagram. Increased pressure from the Green movement will increase the demand for environmental services and products. The increased demand will encourage more investments. In turn, this will lead to competition and increased innovation. Poor awareness and less pressure from the Green movement, for example, can reduce the demand for environmental services. Increased demand for environmental services and products will result in a demand for natural and environmentally friendly products. The main environmental products emerging are all plant-based and include flavours, colours, detergents and pesticides.

The contextual mapping of the technology of natural products, given in figure 26, shows that the demand for those are bound to increase.

Advantages and limitations of an influence diagram: The method is indicative. It does not provide any quantitative relationship. An influence diagram is a general representation of relationships, but does not capture the precise

Figure 26. Green products technology: influence diagram



relationship. Nevertheless, it is a useful tool for indicating the direction of influence.

Morphological analysis

Principle: Morphological analysis is the analysis of structural relationships in a technology or product domain.

Method: The method analyses structural relationships in order to identify likely trends in technology. An analysis of agricultural technology shows that there are several levels, and for each level, a number of alternative product concepts are emerging.

Example: The levels in agricultural technology are:

- Land systems
- Irrigation systems
- Nutrient systems
- Growth systems

The emerging technological options are identified using a morphological matrix, presented in table 8 below.

Table 8. Morphological analysis: an example

Subsystem	*Alternative 1*	*Alternative 2*	*Alternative 3*
Land	Power tiller	Tractor	Hydroponics
Irrigation	High efficiency pumps	Sprinkler irrigation	Drip irrigation
Nutrient	Chemical fertilizer	Biofertilizer	Blue-green algae
Growth	Plant growth regulators	Plant growth hormones	Plant growth stimulators

In the case of land for high-value products, the technological trend is to use hydroponics. In irrigation, the trend is to increasingly employ drip irrigation to optimize water utilization. In the case of nutrients, the trend is to use biofertilizers. Monitoring shows that for growth-regulation management systems, there are three alternative options emerging. Monitoring also shows that growth regulators are in the early phase of growth. A number of applications are emerging and what is needed is a product diffusion strategy, since there are a large number of manufacturers. Monitoring helps to indicate which products are non-toxic and to identify the many patents and manufacturers. The strategy for firms trying to enter this segment is to identify manufacturers who are willing to license technology. Monitoring helps in identifying innovative ideas that intuition alone cannot provide. The application segment that is increasing for growth regulators is the commercial crop market. The crops for which growth regulators are employed are cashew, cocoa, tea, cardamom, coffee, grapes, pineapple, tomato and coconuts.

Advantages and limitations of morphological analysis: This analysis provides information on directional changes, but does not provide any evaluative information for making choices.

Scanning

Principle: One monitoring method is to scan the available commercial and technical information. This involves scanning scientific and patent information and analysing it for signals of change. Scanning is a directed search to understand dynamics and should be used along with mapping techniques.

The scanning process involves the following three elements:

- Gathering inputs and generating information
- Synthesizing and evaluating emerging issues
- Communicating insights

A detailed illustration of a scanning technique using a patent information database is shown below. This technique was applied to map the technology trajectory of the evolution of neem-based products and processes, as illustrated in the study by Agarwal [7] and discussed in the section below.

Monitoring using patents as a source of information

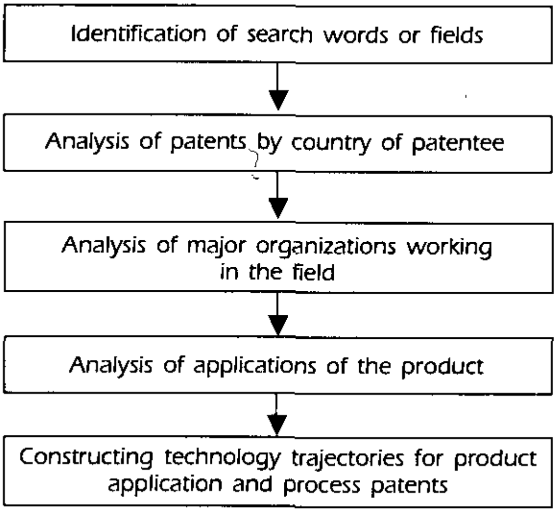
Technology monitoring through patent analysis has been used effectively by corporations for understanding new trends in technology.

Information on patents is highly accessible data that can provide managers with an important historical record of many technologies and suggest areas of future innovations. Patent analysis is very useful in a focused search in several domains including for monitoring of product technology and product application, and the monitoring of competitors' technological activity process technology. Patent analysis is especially useful for the following:

- Comparing relative technology strengths of competing firms
- Assessing sources for technology acquisition
- Assessing potential partners for joint ventures
- Analysing technology trajectories
- Analysing the pace and direction of R & D
- Gaining an understanding of how to bridge the gap between technology development and R & D innovations

An analysis of patents granted over the years gives an indication of the intensity of R & D efforts in a given area. This is the first level of analysis that should be conducted at the country level. The next level is analysis of

Figure 27. Monitoring using patents as a source of information



the ownership of patents by firms, institutions or individuals. The following step is to analyse the direction of growth of technology by analysing the application of patents. The fourth step in technology monitoring is a detailed analysis of patents on related products.

A brief map of the process technology trajectory can be prepared based on such monitoring. Monitoring of patents should include analysis of the technological trends in the manufacturing process. The technology monitoring process using patents is illustrated in figure 27 above.

The process of technology monitoring at an enterprise level can be illustrated using the case study of neem-based pesticides [7].* The case study highlights the need for the continuous scanning of trends in technology if a firm is to be active in a given field. Increasing global competition and the evolution of tighter intellectual property regulations requires that firms institutionalize systems for technology monitoring. This involves detailed patent-analysis systems.

Monitoring patents can be a very useful source of information relating to technology monitoring. Patents reveal trends in technology more clearly than published papers reveal them. By monitoring patents, information can be gleaned about the following aspects:

* The neem is a tree grown all over India. Traditionally, farmers in India have been using neem seed extract and neem seed cakes as well as neem seed oil as pesticides. There has been a global move to use environmentally friendly pesticides. Systematic monitoring of neem-based pesticide technology helped an enterprise in India to become a leader in its field.

- Potential competitors
- Individuals and firms active in the field
- Application trends
- Process development trajectory
- Possible routes that can be adopted
- Examination of possible licensing avenues

Method: Monitoring assumes limited baseline knowledge of the current state of a product, a technology and a market. Organizations need to have an information base that permits inferences to be drawn about driving forces, relationships and future break points. A variety of information sources can be employed such as:

- Empirical data
- Industry analysis
- Technology reviews
- Hints
- Ideas
- Patents
- Predictions
- Signals

The process of gathering inputs is given in figure 28 below and involves the following four steps:

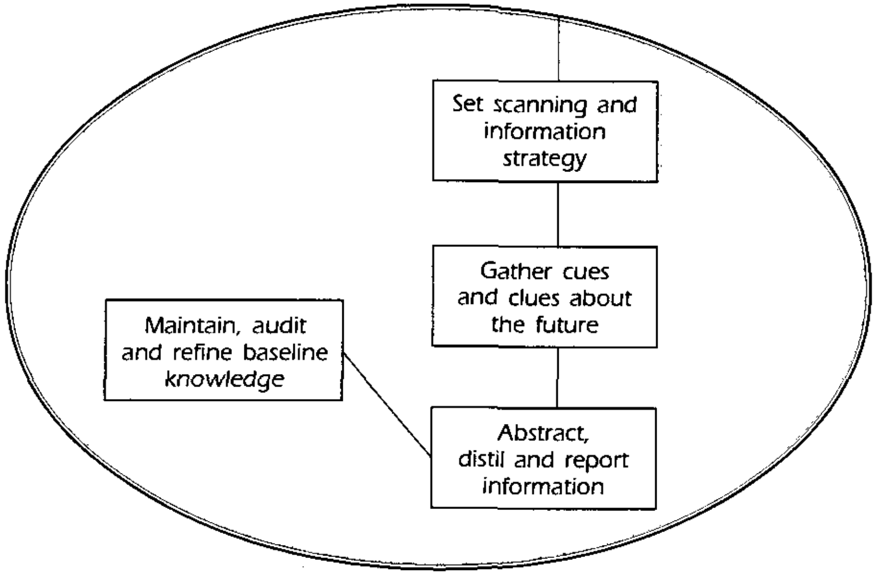
- Plan scanning and information gathering strategy
- Gathering cues and clues about the future
- Maintaining, auditing and refining baseline knowledge about the product/technology/market scenario
- Abstracting, distilling and analysing the information

The sources used for gathering information will be discussed later in the chapter.

Synthesis process: The next step in the scanning methodology will be the synthesis process. This involves collecting all elements of the puzzle and arranging the pieces of information in a cohesive context.

The objective of this step is to show that the information can be combined, compared, contrasted and correlated in ways that produce novel, quantitative and conceptual patterns. The method is schematically

Figure 28. Gathering inputs for monitoring



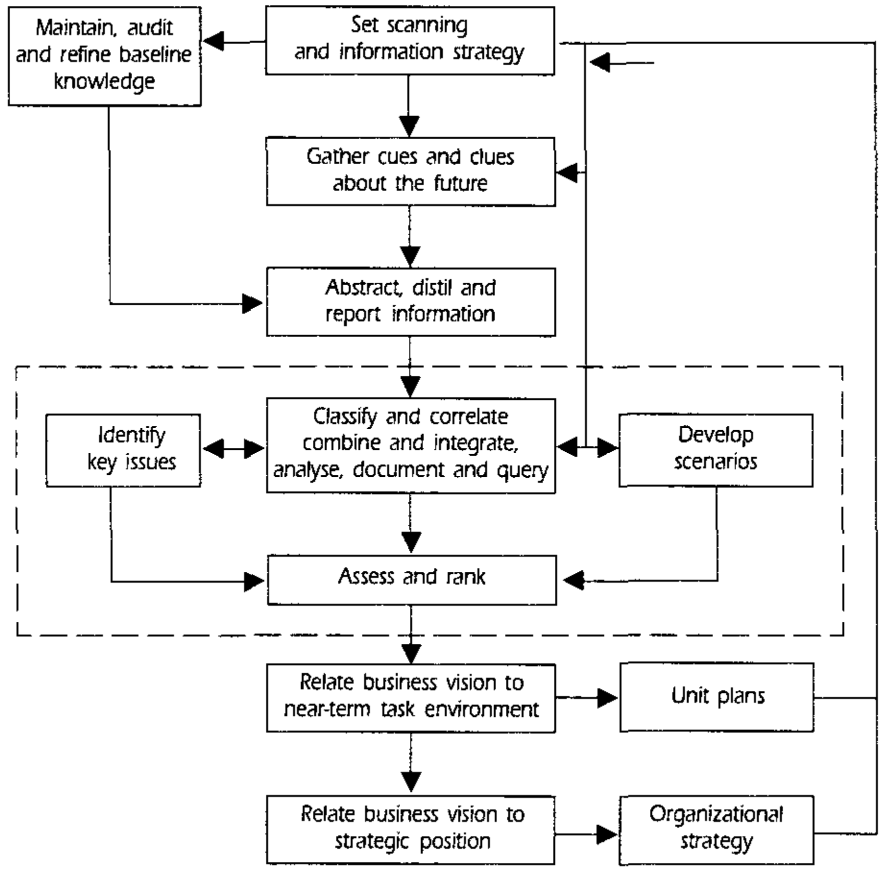
Source: J. D. Stoffels, *A Comprehensive Guide to Environmental Scanning*, Pergamon, Oxford, 1994.

presented in figure 29 below. This will require subjective analysis by an expert. The focus of the scanning process at this stage is the analysis of events, signals and other information, particularly intuitive and inferential data in order that the implications of emerging patterns can be synthesized. The assessment and ranking of issues are carried out after examining the following:

- The extent to which the trend will help or affect the organization (opportunity or threat)
- The possibility of any other cross influences
- Judging the opportune time to respond
- The organization's ability to respond
- Major constraints in moving ahead and whether they can be eliminated

The next step in scanning is to clarify the action agenda using the monitoring results. Since scanning is an integrative technique, special efforts are needed to inform the relevant decision makers about strong or dominant signals. Thus, communicating information about scanned signals and creating a strategic vision through executive involvement is the crucial

Figure 29. Technology monitoring using scanning



Source: J. D. Stoffels, *A Comprehensive Guide to Environmental Scanning*, Pergamon, Oxford, 1994.

step. The objective is to make an integrated response in order that a synthesis can be made of collected information and strategic action. There should be a total strategy in which planners and implementers work together, through joint analysis and joint design of strategic response.

Advantages and limitations of scanning: The success of this technique depends on collecting information from diverse sources and consequently on devising a corporate response.

Modelling

The third set of techniques used for modelling includes trend analysis, substitution curves and growth curves.

Trend analysis

Principle: Trend analysis uses extrapolation techniques to analyse the emerging trends.

Method: Linear or exponential extrapolation is done using a measure or index of performance. In the case of a plastic material, it can be strength- or high-temperature performance. The method assumes that any future trend will be an extension of the past. Historical data on a specific parameter is collected and, using statistical analysis, extrapolated to obtain the future trend. It is very useful for understanding the broad direction of technological change in a given field.

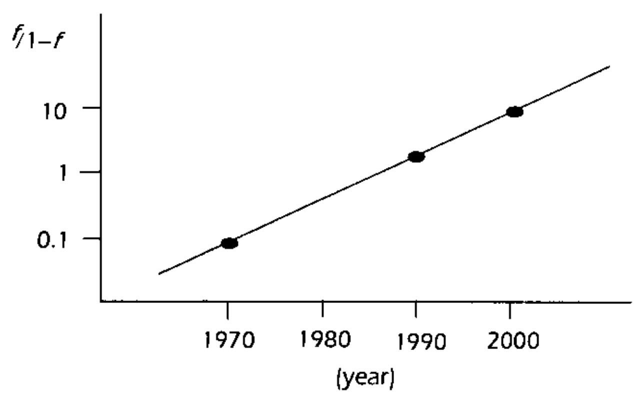
Advantages and limitations of trend analysis: This is a very convenient and useful method for analysing trends with a limited amount of data. However, it cannot be used for understanding long-term technological trends. This method should be used along with other methods to obtain useful results for decision-making.

Substitution

Principle: The substitution technique is a variation of extrapolation. It predicts the rate of substitution of one technology by another. A substitution relationship is a linearized relationship in which a technological change is considered as a substitution process.

Method: In this method, the rate of substitution is measured and plotted. The degree of substitution is measured as f and this is the proportion of new technology in the total market. The substitution curve is shown in figure 30 below.

Figure 30. A typical substitution curve



The plot of f / 1-f versus time in a semilog graph will be a linear plot that can be extrapolated easily to predict the future direction of a given technology as shown in figure 30. The plot can indicate the rate of substitution and whether substitution is moving towards completion or not.

In the expression

$$f = \frac{\text{share of new technology}}{\text{share of new technology + share of old technology}}$$

For example, in a washing chemicals industry:

$$f = \frac{\text{Detergents in use}}{\begin{array}{c}\text{detergents in use + soaps in use}\\ \text{(total washing material)}\end{array}}$$

Legislation regarding the percentage of electric or no-emission vehicles can be plotted on a technology-substitution curve to understand the technological diffusion trend of electric vehicles.

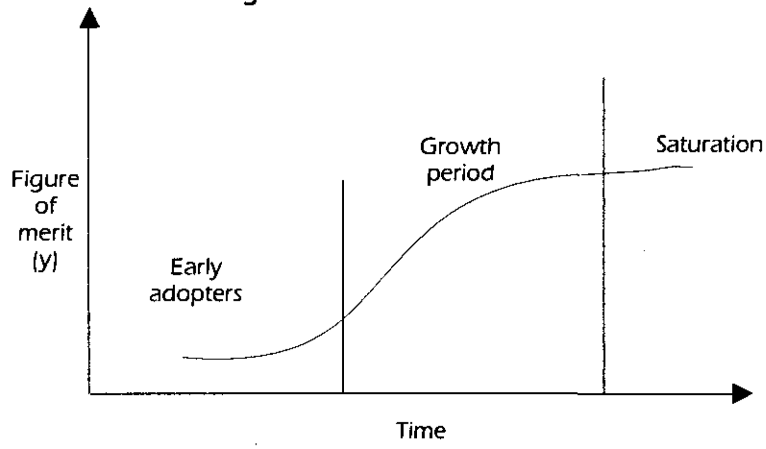
Advantages and limitations of the substitution technique: This method is simple to use, provided a reliable indicator of a technological trend can be identified. It requires some historical data for preparing the extrapolation. If substitution reaches 10 per cent, the new technology will completely substitute the old. If substitution does not proceed beyond 25 per cent, the substitution does not go to completion. It is a generic method and is applicable to all major substitutions. It can be of use in cases where other kinds of information are not available. To get good results, it has to be used in conjunction with other methods.

Growth curve

Principle: Most of the growth phenomena in nature follow an s-shaped curve. Initially, the growth is slow and then accelerates and finally levels off.

Method: In this method, the parameter that represents a specific technological trend is extrapolated over time. The curve has an "s-form", as shown in figure 31 below.

Figure 31. Growth curve



The growth curve can be linearized easily. It is represented as:

$$Y = \frac{L}{1 + Ae^{-Bt}}$$

where

Y = parameter representing performance of the technology in question

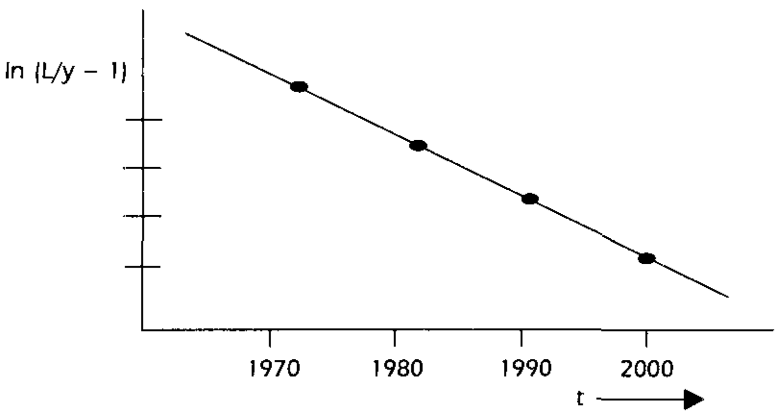
L = limit of growth

T = time

A and B = constants

This curve can be linearized by readjusting the equation and plotting as shown in figure 32 below.

Figure 32. Linearized growth curve



Advantages and limitations of the growth curve approach: This approach is extremely useful for monitoring growth trends of new products. It requires some historic data.

Subjective

In some organizations where the work involves problem solving, certain subjective techniques for eliciting expert opinion have been developed. The disadvantages of group interaction processes are avoided and the positive aspects of face-to-face intervention are captured. One of the widely used methods is Delphi.

Delphi

Principle: Delphi is a programmed sequential questionnaire approach used for eliciting expert opinion while ensuring anonymity.

Method: This method uses a series of questionnaires. The objective is to arrive at a consensus on specific technological trends, options or configurations. In two or three rounds, it attempts to obtain a consensus through anonymous interaction.

Advantages and limitations of Delphi: Minority opinion is taken into account. The method is time-consuming, as it requires both time to conduct and time to design the questionnaire. In addition, it is a method that needs to be used in conjunction with other major techniques. Without a strong database, Delphi can provide no more than an illusory consensus.

The most important issue in monitoring is the collection and use of appropriate information. Another issue is that of devising a strategy for interaction among functional experts. Consulting a wide range of sources for scanning and monitoring trends is also a very important aspect of monitoring.

Pitfalls of monitoring

Monitoring reduces uncertainty but does not completely eliminate it. The use of monitoring tools helps in eliminating subjective biases, but in many cases individual biases are superimposed on the inputs. Some of the major pitfalls encountered in technology monitoring are discussed below.

Technology trends are evolutionary

Certain new technologies are not able to gain market dominance because older technologies improve when a competing technology arrives on the scene. For example, cathode ray technology for display devices started improving when liquid crystal displays entered the market. The potential for improvement of existing technology should be examined when assessing a new technology, especially when larger players have major stakes in the existing technology.

Failure to anticipate obstacles

Nuclear technology did not catch on, although it had some inherent advantages. For example, conventional coal-combustion technology improved considerably and nuclear waste disposal issues depressed the growth of nuclear power technology. It is important to take into account the possible changes in competing technologies, as well as the potential obstacles, before assessing the possible trajectory of a new technology or a new business opportunity being monitored. An example of an unforeseen stumbling block would be bioengineered tomatoes, an issue that has given rise to considerable negative reaction in many communities in the developed world.

Innovators do not look ahead

Many innovators do not fully understand the commercial value of new innovations, especially in the beginning of the innovation cycle.

> "The ability to foresee commercial possibilities in new technologies is perhaps an even more valuable skill than being able to invent them."
>
> "Perhaps no single application of the laser has been more profound than its use in telecommunications, where together with fibre optics it is revolutionizing transmission."
>
> "And yet, the patent lawyers at Bell Labs were initially unwilling even to apply for a patent on the laser, on grounds that such an invention had no possible relevance to the telephone industry."
>
> N. Rosenberg [8]

Expert bias

One of the major pitfalls in monitoring is the failure to analyse implications in related areas. Drug researchers have started only recently to consider the possibilities of using natural molecules. Pharmaceutical chemists mainly had training in organic chemistry. Many new drug firms, however, are searching for new molecules using ideas from "traditional medicine". To be useful for an organization, monitoring should be performed in a multidisciplinary mode using interactive group processes in which biases are eliminated. The emergence of the concept "biodiversity prospecting", similar to mineral prospecting, has a very recent origin [9]. The signing of a long-term contract for "biodiversity prospecting" by Merck & Co., Inc. of the United States and the Instituto Nacional de Biodiversidad (INBio), Costa Rica, highlights the need to go beyond traditional disciplines in order to generate innovative options for using traditional plant species.

Lack of resources

In view of the uncertainties attached to the process of innovation, it is not surprising that firms trying to innovate have often experienced high failure rates [8]. Innovations require large investments to make them into potentially usable technologies. Many important innovations are lost because the level of investment required to make commercialization and market development possible is not made. This is especially true for small innovators. Technology monitoring efforts help in bringing together innovators and market development forces—provided innovators, technology developers, financial agencies and marketing agencies are involved in the process.

Inability to combine intuitive and judgemental wisdom

Intuitive and judgemental wisdom in many cases provide different perspectives, since they use inherently different ways of reasoning to arrive at decisions [10]. Monitoring can provide useful results only when the differing perspectives can be understood and then integrated.

Absence of a product champion

The organizational support for a new idea will depend on the influence that the

> "If you know the *enemy* and know *yourself* you need not fear the results of a hundred battles.
> If you know *yourself* but not the *enemy*, for every *victory* gained you will also suffer a *defeat*.
> If you know neither the *enemy* nor *yourself*, you will *succumb* in every battle."
>
> Sun-Tzu

innovator has in the organization as well as the culture of the organization [10]. Unless there is a receptive culture and an institutional arrangement for monitoring and evaluating emerging technologies, organizations will not be able to realize the full potential of new ideas. The role of top management lies in providing a receptive culture for new ideas generated by technology monitoring.

Technology forecasting and technology monitoring

Technology forecasting is one of the techniques used for looking ahead. It is a method that extends the horizon of planning. Technology monitoring provides inputs for carrying out comprehensive technology-forecasting exercises. As indicated in box 1 of chapter 1, technology monitoring is oriented towards assessing business opportunities and towards clarifying future goals. Technology forecasting develops ways to engineer the future once the direction of the technology trajectory is clarified. The techniques used for both are complementary. The scope of technology forecasting is broader and the time horizon longer. Emerging global competition and global business opportunities have made technology increasingly relevant. Monitoring assists in gauging capabilities, particularly how these capabilities measure up to competitors' strengths.

Summing up

Technology monitoring is being practised and effectively used at regional, national and enterprise levels (see annex II for case studies). Monitoring patents is becoming an effective method of monitoring and assessing trends in technology. The availability of patent databases on CD-ROM is facilitating

> "Industrial technology monitoring tends to be fairly limited in developing countries. This is largely because of the formidable costs associated with carrying out such monitoring activities, especially for smaller firms." [11]

this approach, making it possibly the quickest approach to monitoring.

One of the ways of reducing the cost of performing technology monitoring is to pool monitoring efforts and share the scanning costs. Through such a networking arrangement, more sources can be monitored and more users can be serviced. Using existing institutional networks is the most cost-effective route as shown by the Technology Information and Assessment Council (TIFAC) experience [12]. Regional networks, established by linking national and enterprise level monitoring networks, is the most feasible option for developing countries.

References

1. F. J. Aguilar, *Scanning the Business Environment*, Macmillan, New York, 1967.
2. J. D. Stoffels, *Strategic Issues Management: A Comprehensive Guide to Environmental Scanning*, Pergamon, Oxford, 1994.
3. W. B. Ashton and G. S. Stacey, "Technical Intelligence in Business", *International Journal of Technology Management*, vol. 10, No. 1, 1995, pp. 79-104.
4. P. Bye and J. Chanaron, "Technology Trajectories and Strategies", *International Journal of Technology Management*, vol. 10, No. 1, 1995, pp. 45-66.
5. J. Courtial and A. Sigogneau, "How to use scientific and technological information to reveal strategic technologies", *International Journal of Technology Management*, vol. 10, No. 1, 1995, pp. 31-44.
6. J. P. Martino, *Technological Forecasting for Decision Making*, Elsevier, New York, 1992.
7. A. Agarwal, "What is in a *Neem*", *Down to Earth*, vol. 4, No. 20, March 1996.
8. N. Rosenberg, "Why Technology Forecasting Often Fails", *Futurist*, vol. 29, No. 4, 1995, pp. 16-21.
9. W. V. Reid et al., *Biodiversity Prospecting: Using Genetic Resources for Sustainable Development*, World Resources Institute, Washington, D.C., 1993.
10. H. A. Linstone, *Multiple Perspectives for Decision Making: Bridging the Gap between Analysis and Action*, Elsevier Science Publishing Co., New York, 1984.
11. Hagedoorn and R. Acharya, "Technology Monitoring and Assessment: International Trends", Meeting on Cooperation in Technology Monitoring in Developing Countries, UNIDO, 22-25 November 1994, New Delhi.
12. Y. S. Rajan, "Role of TIFAC in Accelerating Technological Development", paper presented by the Technology Information, Forecasting and Assessment Council at Assocham, 2 September 1994, New Delhi.

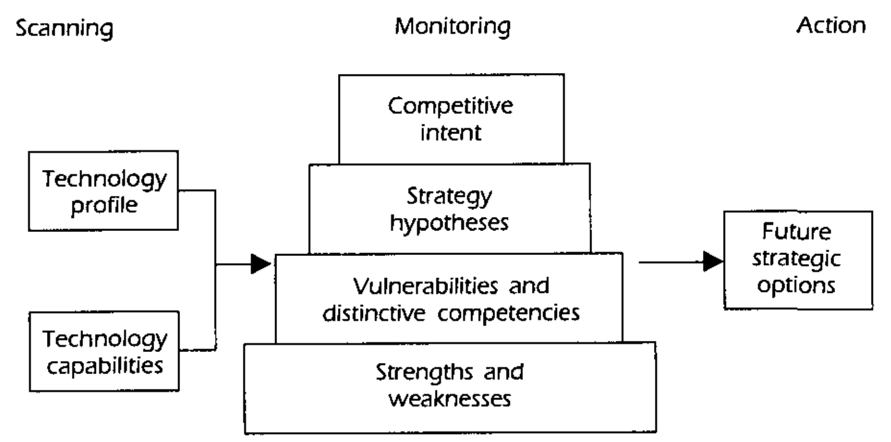
5. Skills and competencies required for technology monitoring

Technology monitoring requires certain organizational and individual competencies that may not be available in all organizations. Competencies may need to be acquired or developed. Technology monitoring normally involves two distinct activities, namely:

- Monitoring the specific technological trends that can improve the existing enterprise operations
- Monitoring and analysing the overall business-related technological changes and newer opportunities

Technology scanning and monitoring require competencies for clarifying future action and evolving strategic options as shown in figure 33 below. It has been found that many organizations, especially in developing countries, have yet to evolve competencies and organizational systems for processing and utilizing signals of change relating to broad trends in technology.

Figure 33. Inferring future strategies



Source: D. Bernhard, *Perfectly Legal Competitor Intelligence*, Pitman, London, 1993.

Competencies for monitoring

As shown in figure 33 above, technology monitoring requires a variety of competencies. Scanning the profile of an identified technology is the starting point of the process. This requires a clear ability to understand industrial and technological trends. It is a cognitive capability and requires "learning by doing". The competencies required for monitoring [1] can be categorized into four types:

- *Detecting signals of change*: Competence in scanning the technological environment so as to detect signals of new opportunities in technology such as new products, new processes and new applications in the overall business context. Essentially, this calls for the ability to eliminate spurious signals. Information overload has meant this ability is becoming more important;
- *Assessing the technology trajectory*: Competence in monitoring specific technological trends related to business and new opportunities—once the broad trends are understood—and relating them in turn to business. This requires an ability both to assess which option is likely to be the winner and to assess technological and economic trade-offs;
- *Identifying specific technologies*: Competence for analysing the future direction of technological changes. The aim is to identify threats and opportunities in order to design organizational responses for coping with a changing technological environment. Essentially, the term refers to the competence required when designing and developing organizational road maps for the future, from the results of monitoring exercises;
- *Implementing specific action programmes*: Competence for assessing current and future technological changes and for identifying the strategic implications of such change. The focus is on the specific organizational context and how specific future strategic options are integrated into the corporate decision-making system.

Though the competencies needed for each of the preceding points are specific, it is necessary to have a broad understanding of the utility and application of technology monitoring in an organization. Two major problems are frequently encountered. Firstly, some of the information related to trends in technology is available only through informal channels and in non-quantified forms. Getting it and using it have been problematic issues. Secondly, in many organizations, monitoring is located in the business units that have a short-term focus. Assimilating such information and converting it into strategic action initiatives tend to require considerable effort in terms of word coordination.

The present manual focuses on the use of technology monitoring at the industry or enterprise level, since in any liberalized economy, the beneficiaries and users of technology monitoring are enterprises. The most important and critical competence needed for technology monitoring is a "forward-looking ability", that is, the ability to pick winning technologies ahead of others [2]. This is a combination of intuitive and conceptual skills. Recently such capabilities have been termed "foresight". Foresight helps reveal options not seen by others. The ability to identify generic technologies requires development and practice. Japanese industrial dominance in lasers, memories, sensors, robots and displays is an illustration of such forward-looking competence. Japanese firms as well as the Ministry of International Trade and Industry in Japan have evolved institutional systems, information support and competencies for such an exercise on a regular basis [3]. The advantage of such a skill is that it enables enterprises to plan their technology strategy based on the results of monitoring.

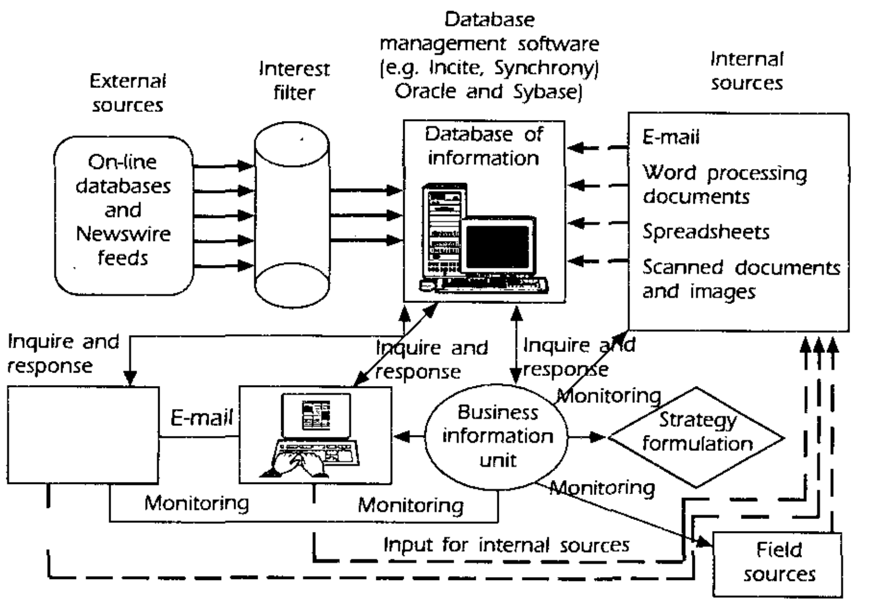
Monitoring from a user perspective

The initial steps involved in monitoring, namely, gathering and scanning activities, require routine capabilities and competencies for analysing business-technology interactions. Subsequent steps are evaluative and require insight into the technology diffusion process and its specific business implications. Mastering the monitoring process at the enterprise level requires evaluative analysis. In addition, capabilities for scanning and integrating results into the strategic information system and strategic decision-making process are also needed. The results of monitoring should be circulated among executives and synthesized before initiating specific enterprise-wide technology forecasting and assessment exercises. A typical enterprise-wide technology monitoring system that indicates various elements is presented in figure 34 below.

Integration of technology monitoring into the strategic decision-making system will help enterprises to exploit opportunities quickly. At either the user level or the enterprise level, the externally collected monitoring results need to be integrated into the corporate-level decision support system. The competencies needed for implementing a technology monitoring system will depend on a number of parameters, including:

- *Size of the firm*: Large firms are required to undertake comprehensive monitoring in order to survive and grow. It is essential that they look well into the future. Without monitoring, the survival of large firms in a competitive environment may be more at risk;

Figure 34. A technology monitoring system at enterprise level



- *High technology*: A high-technology firm needs to be strong in monitoring because of the dynamic nature of technology. Obsolescence occurs quickly and new products are introduced frequently;
- *Globalized firms*: Globalized firms need to monitor a number of technological changes, effectively including new product introduction, technological obsolescence and the emergence of new markets;
- *Small enterprises*: Monitoring is important for small enterprises, as it allows them to scan for new ideas, new opportunities, licensing options, market potential etc.

Competencies needed for managing a monitoring network

The major competencies needed to ensure an effective technology monitoring system [4] are implementing the monitoring network system and managing the network system.

Implementing the network

The main issues in implementing a technology monitoring network are:

- Choice of technology to be used
- Network architecture and interconnectedness

- Developing protocols
- Communication services
- Interconnecting networks
- User characteristics and needs

Technology

Networks connect many users to the same system of computing power, thus the system needs to be user-friendly, reliable and secure. The technology currently used is usually a PC network or a client-server system. PC networks are user-friendly and permit sharing of data files. PC-based local area network evolution permits interconnection of many types of users and systems. The present technology allows networking of hundreds of personal computers. The first major issue is selecting the appropriate mix of technology that can satisfy the needs of various users if the network is large. If the system is for a small firm, the focus should be on satisfying the employees within the same enterprise. Since computer technology is changing rapidly, the network and the hardware should be amenable to upgrading. The basic skill required is the ability to identify the technology needed for designing a multi-user open architecture with a high level of flexibility for the technology monitoring network.

Network architecture

The architecture of the selected technology monitoring network needs to have the capacity to support a wide variety of configurations in order for it to address the changing demands of users and future requirements. The network architecture defines protocols, messages and standards to which machines and software packages must conform in order to achieve given technology monitoring outputs. Although network architecture varies with regard to the connection between the generators of information and the users of the technology monitoring system, the architecture currently emerging as the standard is the client-server based three-tiered architecture, involving the application functions at the following three levels:

- Presentation (user interface): supporting human computer interaction

- Functionality—providing connections that run on one or more computers to:
  All existing users
  New databases (national and international)
  Provide on-line services
  Accepting real-time data

Process and formulate data for preparing reports
Provide interconnectivity with various user interfaces
Maintain security, audit trial, version control etc.

- Flexibility—systems accommodating existing systems and applications that are capable of accepting new databases and formats with minimum transition effort from the user side

The architecture should be designed with sufficient flexibility so that it is configured for open systems. It needs the ability to provide connectivity to multiple users and different interfacing devices. To achieve this, a good understanding of user requirements and computer networking architecture is required.

Developing protocols

When implementing a technology monitoring network, it is essential to plan the data communication protocols. Whether it is a monitoring system at national level or one at enterprise level, both need to have clearly defined communication protocols. The data communication protocols are used for coordinating the exchange of information between different network devices and categories of users. Implementing a technology monitoring network requires a number of protocols to be followed, together with several basic structures. The networking at firm level involves linking agents such as:

- The technology monitoring group
- Corporate headquarters
- Local area networks
- Information vendors and network service providers

The national system will be similar in structure, but users can access it through dial-up modem or a leased line.

In recent years, it has become essential for both national systems and firm-level systems to have Internet access. It is important that provision for the Internet be made at the design stage. Information availability on-line through the Internet has made access to a variety of sources easy, at low collection costs.

Communication services

If the technology monitoring system needs to provide colour pictures and drawings of high quality for engineering, for example, it will require advanced communication support with a high bandwidth. A national technology monitoring system should be capable of interconnecting many corporate systems. While designing technology monitoring systems at the national level, care should be taken to examine the status of the national telecom infrastructure.

Interconnectivity of networks

Many data networks or monitoring networks may exist in any given country. It is therefore important to have the capability to interconnect different networks. This will ensure that the monitoring system is comprehensive and that the collection costs are minimized.

Assessment of user needs

One of the most important elements needed for implementing a technology monitoring system is the ability to design a system that satisfies the needs of most users. This requires a detailed user survey before the design and implementation of a technology monitoring system takes place. The assessment should be done in terms of:

- Topics
- Areas of coverage
- Depth of coverage
- Details required
- Relevant geographic area
- Technical information
- R & D activities
- Areas active in patenting
- Product expertise
- New product introductions
- Commercial and financial information
- Collaborations
- Acquisitions
- Diversification
- Alliances
- Required outputs

Different users will require different aspects to be covered. Integrating user requirements is therefore a crucial competence.

Scanning strategy

Balancing the costs of scanning and analysis is a major issue in designing the scanning strategy and is also the most cost-intensive step. The least-cost strategy is to use existing specialized agencies to provide information rather than creating an entirely new system. An example of a country using this strategy is India where, at the national level, the strategy was adopted and it was found to be very cost-effective. The system was designed and implemented in a short time. The structure of the system is discussed in annex II.

Data security

Another major competence needed for implementing a network at enterprise, national or regional level, is managing user rights and security access. User or account permissions and security are controlled by network console programmes. Different network operating systems have different degrees of flexibility in their definition of permissions. An enterprise-level monitoring system should incorporate the following security features:

- ❑ A defined group of user accounts with similar permissions
- ❑ Segregated sensitive proprietary information
- ❑ Firewalls constructed against unauthorized use in the case of sensitive or proprietary information
- ❑ Rights assigned to a user on a group or individual basis
- ❑ An assigned special batch file that is executed each time a user logs into the network so that the original data set is unaltered by the user operation
- ❑ Access to data directories is managed and places limits on the amount of space used by any account
- ❑ Designed and installed virus detection and protection systems
- ❑ Designed financial limits for users if there are user chargers or data communication targets

Designing security for monitoring networks at both enterprise and national level is crucial. A detailed system of checks needed for information security is given in box 3 below. Software packages are available for some functions.

Competence for network management

Competence for the management of networks consists of configuring, monitoring, controlling and analysing the resources available for technology

Box 3. Information security checklist

It is doubtful that any data-security system can completely foil a skilled and determined intruder. The American Society for Industrial Security suggests several measures that will at least provide a strong first line of defence:

- ✓ Conduct a detailed audit (using an experienced consultant, if necessary) to identify your intellectual property and the impact of its loss to a competitor.
- ✓ Design and disseminate a written policy on handling confidential material when responding to unsolicited phone enquiries, for example, or dealing with the media.
- ✓ Develop non-disclosure agreements with customers, partners, vendors, maintenance personnel, new and exiting employees.
- ✓ Implement and enforce rules for classifying, storing and destroying sensitive materials.
- ✓ Develop and propagate a need-to-know policy for employees, customers and visitors.
- ✓ Have an expert periodically check your voice, fax and data systems for safeguards against unauthorized access.
- ✓ Hold regular employee seminars to warn against discussing company business in public.
- ✓ Restrict access to fax machines, copiers and other data-duplication equipment.

Source: H. G. Deyoung, "Intellectual Property: Among Us", Industrial Week, vol. 245, No. 12, 1996, pp. 12-16.

monitoring networks, optimizing the use of those resources and preventing and solving user problems. The most important competence is that of assisting network administrators with the management of day-to-day tasks that are increasingly diverse and can include adding new users, manipulating printer queues and scheduling back-ups. Among such tasks, the most important network management activity is the provision of timely back-up and archiving of network files.

Two of the most annoying problems for administration of technology monitoring networks are the unmanageable number of software versions that must be supported and the continuous evaluation of new software that takes place. The most effective way of handling those problems is to have a standard for network management so as to provide simultaneous administration and management of devices from different users by a single console. Open system interconnection eases the problem of standards for communicating between computers. The problem becomes critical when a regional network consisting of a number of countries needs to be implemented.

Use of the Internet for monitoring

Strategic decision-making relating to technology requires external information generated by multiple sources. The availability, flow and quality of external information are not as controllable as internal information [6]. Developing an Internet capability contributes significantly to obtaining external information. The rapid growth and evolution of the Internet has added to its value as a basic tool in the workplace. Table 9 shows that the Internet can

Table 9. Internet as a source for monitoring

	Monitoring for task environment			
Information content	*Competitors*	*Suppliers*	*Consumers*	*Distributors*
Status	Medium	High	High	High
Outcomes	High	High	Low	High
Actions	Low	Low	Low	Low
Intentions and opinions	Low	Low	High	Low
	Monitoring for business entities			
	Technological	*Regulatory*	*Economic*	
Status	High	High	High	
Outcomes	High	High	High	
Actions	High	High	High	
Intentions and opinions	High	High	High	

Source: B. S. Pawar and R. Sharda, "Obtaining Business Intelligence on the Internet", *Long Range Planning*, vol. 30, No. 1, 1997, pp. 110-121.

be a major external source for monitoring specific task-related business environments, as well as general business contexts. The Internet can provide information relating to technology monitoring quickly and at relatively low cost. The monitoring focus can differ considerably, as shown in table 10. For the four monitoring modes, the Internet can be a major enabler. The various Internet utilities that can be used for monitoring are given in table 11. At the enterprise level, efforts have been made to encourage and train employees in using the Internet. The focus has been on integrating the information sourced from the Internet, as well as the other inputs used for monitoring exercises. The importance of such a capability will increase in the future.

Issues for developing countries

Computer connectivity is low in developing countries (especially in low-income countries). In most developed countries, commercial databases and network support systems are well developed, whereas in developing countries, the

Table 10. Sources for monitoring

Scanning mode	*Information requirements*	*Extent of structure*	*Nature of Focus*	*Information search*	*Source*
Undirected viewing	Not known	Unstructured	No focus	Exploratory	Not known
Conditioned viewing	More or less clear	Unstructured	Signals to possible needs	Exploratory with alert receptivity	Partly known
Informal search	Specific	Unstructured	Information on present needs	Active/focused vigilance	Known and selected
Formal search	Clear and specific	Structured	Information on specific recurring issues	Deliberate effort	Prespecified

Source: B. S. Pawar and R. Sharda, "Obtaining Business Intelligence on the Internet", *Long Range Planning,* vol. 30, No. 1, 1997, pp. 110-121.

Table 11. Monitoring for information acquisition and the suitability of Internet utilities

Internet utility	*Undirected viewing*	*Conditioned viewing*	*Informal search*	*Formal search*
Newsgroups	Low	Medium	Low	Low
Lists	Medium	Medium	Low	Low
E-mail	Low	Low	High	Low
Telnet	Low	Low	Low	High
FTP	Low	Low	Low	High
Gophers	High	High	High	High
WWW and Gophers	High	High	High	High
WAIS	Medium	Medium	High	High

Source: B. S. Pawar and R. Sharda, "Obtaining Business Intelligence on the Internet", *Long Range Planning,* vol. 30, No. 1, 1997, pp. 110-121.

information infrastructure is still emerging. The most effective way to proceed is to use existing institutions and link them in order to obtain a national network. It is essential to have a common design, common format and common network protocols. The goal must be to evolve a distributed architecture in order that each subject is handled by a specialized agency. Such a structure will minimize incremental investments and reduce the duplication of efforts. However, all information needed is not available on-line. Initially, it may be better to have a manual system where computer connectivity is low.

The only way to ensure that monitoring results are available is to ensure that they are available in hardcopy. Ideally, the focus of technology monitoring in developing countries is on:

- Utilizing technology monitoring results
- Communicating the results of monitoring to decision makers who play a major role in decision-making

- ❑ Evolving systems for integrating technology monitoring and technological choice in decision-making systems at corporate and national levels

These are inherently more difficult processes than designing and implementing a technology monitoring network. It is crucial that institutional systems and routines evolve in order for information to be disseminated and for the results of technology monitoring to be communicated to the actual decision makers.

Some of the technological options used in the design of a technology monitoring system are indicated in table 12. The options depend on the type of users, the nature of markets and the number of technologies to be employed.

Table 12. Selecting technology for a monitoring system

	Manual system	*Internet and E-mail*	*Enterprise wide inter-connected*	*PC-based centralized system*	*Large system*	*Many inter-connected networks*
National level system				3	3	3
Small organization	3			3		
Low volume	3	3		3		
High volume	3				3	
Few products	3	3		3		
Complex product mix	3				3	
Few competitors	3			3		
Many competitors	3				3	
Shared markets and competitors	3	3	3		3	
Large divisionalized multi-product firm	3	3	3	3	3	
Stable market	3			3		
Dynamic market	3	3	3	3		

Source: Adapted from L. M. Fuld, *The New Competitor Intelligence*, Wiley, New York, 1995.

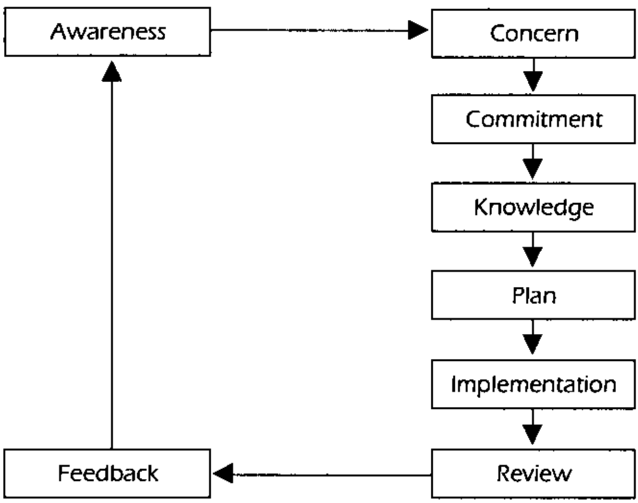
References

1. B. Bowonder, "Technology Monitoring at the Enterprise Level", paper prepared for the Meeting on Cooperation in Technology Monitoring in Developing Countries, UNIDO, Vienna, 22-25 November 1994.
2. J. Irvine and B. R. Martin, *Foresight in Science: Picking the Winners*, Pinter, London, 1984.
3. B. Bowonder and T. Miyake, "Technological Forecasting in Japan", *Futures*, vol. 25, No. 7, 1993, pp. 757-777.
4. D. Bernhardt, *Perfectly Legal Competitor Intelligence: How to Get it, Use it, and Profit from it*, Pitman, London, 1993.

6. Implementation of technology monitoring

Implementation is one of the major issues relating to technology monitoring. The diffusion of a technology monitoring process follows a typical cycle of change, as shown in figure 35 below, where the major driving force is managerial commitment.

Figure 35. Change process cycle



> Creating a commitment to implementation and action is the most crucial element in the technology monitoring sequence.
> Awareness and concern are the major triggers for change and commitment.

The success of implementation depends on the ability of concerned staff to commit to:

- ❑ The implementation of technology monitoring activities within the corporation
- ❑ An active role in influencing business decisions

The ability of technology monitoring experts to influence business decisions will depend upon their ability to relate monitoring results to business opportunities. This requires highly developed conceptual skills.

The integration of monitoring results and strategic actions can also be achieved through joint work and a continuous exchange of results.

Organizational prerequisites

Some of the major organizational prerequisites for implementing technology monitoring are discussed below.

Receptive organizational culture

Acceptance and implementation of technology monitoring need a culture that is supportive of change. A receptive culture can be developed or nurtured and can be defined in terms of a bundle of routines that are receptive to change and continuous learning.

Appropriate business process

The second prerequisite needed for ensuring implementation of technology monitoring is a set of compatible organizational or business processes. They assist the organization in implementing changes through a series of organizational procedures in response to environmental changes or competitive pressures. The appropriate processes include:

- Regular scanning efforts
- Review of scanning reports
- Participative discussions
- Managerial review

Cross-functional teams

One of the major prerequisites needed for the acceptance of monitoring results is the creation of a cross-functional team that can integrate various organizational perspectives. Without cross-functional teaming, the content as well as analysis of trends will acquire certain functional biases and prejudices. Cross-functional teams moderate the biases and facilitate the acceptance of results through the incorporation of multiple perspectives.

Entrepreneurial orientation

The outputs of technology monitoring will be used effectively only if the executives concerned take an entrepreneurial approach. Instilling an entrepreneurial attitude among executives and encouraging them to become opportunity seekers will help improve the commitment to using technology monitoring.

Decision support systems

The quality of technology monitoring outputs will depend on decision support systems available at the enterprise, industry and national levels. The basic elements of the decision support system are:

- A scanning schedule
- An analysis procedure
- A database
- A data retrieval and storage system

Developing an appropriate decision support system is a major challenge. It requires understanding user needs through a detailed user-needs survey. Designing an appropriate decision support system is part of designing a system for technology monitoring.

Competencies

Technology monitoring has certain specific organizational requirements [11], including competencies for:

- Scanning new ideas in technology or product concepts so as to identify new or emerging business opportunities
- Identifying and interpreting specific trends in technology
- Predicting trends in a specific business area with a reasonable amount of reliability
- Assessing trends and sensitizing decision makers
- Utilizing the results of monitoring by integrating trends in technology and business opportunities

It is necessary to develop such competencies at various levels.

Communication

Another major organizational prerequisite for the successful implementation of technology monitoring is an excellent corporate communication system that facilitates the interfunctional cross-fertilization of new ideas. This needs to be followed by a cross-functional screening mechanism. A regular communication mechanism for the dissemination of new ideas followed by a cross-functional group interaction improves the acceptance of new ideas. The technology infrastructure, such as database and computer technology, is not an end in itself but merely a means to an end [2]. Technology monitoring is a people process and requires an appropriate communication system. The goal of monitoring is to decipher early signals from the competitive arena and to combat corporate blindspots through continuous interaction. This requires both oral and verbal inputs.

Hierarchical information needs

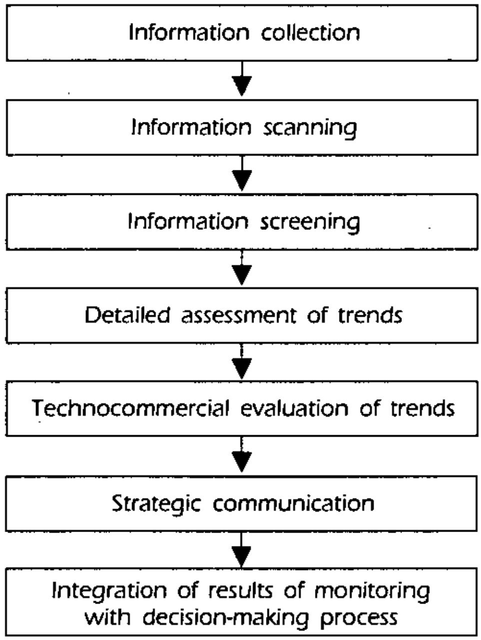
The next issue in technology monitoring is the packaging of information. A corporate technology monitoring system needs to provide a variety of information. Technology monitoring is essentially a hierarchical activity. It begins with the lowest level—a database of raw information. From this information, a variety of inputs is produced and distributed widely to various functional heads. The next layer consists of the strategic assessment of information and value-adding. Technology monitoring per se starts at this level. At the next level, further value-adding takes place. At the next level again, more information is added and integrated into the corporate business strategy and decision-making process. The pyramid of organizational information needs is shown in chapter 2, figure 18. The generic process of enterprise-level technology monitoring is given below in figure 36. This would need modification according to the specific requirements of organizational levels that employ technology monitoring.

Operational level

At the operational level, monitoring is used for a number of purposes, such as:

- ❑ Identification of possible process improvements
- ❑ Identification of possibilities for productivity improvements through technology
- ❑ Stimulating creativity
- ❑ Generating ideas for current problem solving

Figure 36. Enterprise-level technology monitoring



At this level, the information required centres on operational aspects and details, as well as on information sources for a focused search, once the direction of change has been indicated by preliminary technology monitoring.

Strategy level

At the strategy level, information is needed on directional changes, new opportunities and threats from new technology. The results of monitoring should:

- Generate ideas that need further analysis and examination
- Ensure alignment of corporate strategy and a long-term technology trajectory

For example, an analysis of trends in computer technology indicates that the Internet, multimedia and virtual reality (among others) are examples of emerging opportunities in technology. In the case where new opportunities for business are being monitored, the current strategy of firms should be such that it is closely aligned with emerging information technology. When trends in information technology are monitored, three critical shifts are revealed in the application area [3]:

- From personal to work group computing
- From isolated systems to integrated systems
- From internal to inter-enterprise computing

Technology monitoring at this level is used for the following:

- Ideas for diversifying business
- Identifying new business opportunities
- Identifying threats to existing business or competition from new products
- Determining trends in technology in order to analyse options concerning internal technology

At this level, information is needed on technological directions and opportunities. Less details are required at this level.

Policy level

At the policy level, it is important to understand the technology trajectory and future options. Monitoring is used to:

- Sensitize decision makers
- Identify partners for potential alliances
- Select strategic options
- Provide support for strategic decision-making

Identifying focal points

Finally, another important issue in monitoring is selecting and identifying monitoring agents or agencies. The agents are needed at:

- Enterprise level
- Country level
- Global regional level

Enterprise level

In smaller organizations, it may be difficult to devote a person exclusively to monitoring. Ideally, in such organizations, an individual with an interest in monitoring and another who is a decision maker should work together. In medium-sized enterprises, it may be possible to assign the monitoring task to one specific expert. It may not be possible to have a large database exclusively for technology monitoring in medium-sized enterprises. It may be easy for such enterprises to use one of the following options for information scanning and analysis:

- Making use of existing institutions that specialize in specific areas for scanning
- Using specialized databases available on CD-ROM or conducting on-line searches by employing major information-vending agencies
- Purchasing technology monitoring reports prepared by consulting organizations such as Stanford Research Institute, Battelle Memorial Institute, Nomura Research Institute and Arthur D. Little, Inc.
- Using consultants and industry specialists for generating industry scenarios for the future

In large enterprises, technology monitoring requires special planning and implementation that takes into account present and future needs. This requires arrangements for:

- Information collection
- Information scanning
- Information screening
- Detailed analysis of trends
- Technocommercial evaluation
- Strategic communication
- Integration with strategic planning

The above points are schematically presented in figure 36. If firms are to survive global competition, they need to look ahead continuously. Technology monitoring plays a key role in this. In large organizations, monitoring should interact closely with the strategic management decision committee, but should not be left to the strategic business units, as the latter's focus is on the short term. In some firms where monitoring is done at the divisional level, the cost of data collection can be high. Furthermore, there is considerable bias in any operational body with regard to monitoring. In large organizations, the following aspects are required for implementing a successful monitoring system:

- Top management commitment for exploiting new opportunities
- Availability of two executives with an aptitude for monitoring
- Inter-functional screening mechanism for weeding out ideas likely to have low impact
- Scanning and integration of outputs with planning executives
- Regular communication with decision makers about emerging scenarios
- Development of a scanning mechanism and a database that can support current as well as future business needs of an organization
- Review of effectiveness of the monitoring process and utilization at its outputs

National level

Independent monitoring efforts can be effective, as shown by the Technology Information, Forecasting and Assessment Council (TIFAC) model used by India and the one employed by South Africa. Both models operate autonomously, but have good linkages with government agencies. TIFAC surveyed the Indian scene and assessed information needs. TIFAC has created an on-line, interactive, spatially dispersed, but universally accessible Technology Information System with a few initial databases known as TIFACLINE. TIFACLINE aims to offer a standardized package in a structured format that is accessible, available and can acquaint users with various emerging technologies. The information covers country-specific and international technologies. The strengths of TIFACLINE lie in providing knowledge-based data available at dispersed expert institutions through an integrated, computerized system. Such information is easily accessible through a computer-modem-telephone line combination. Thus, TIFACLINE builds on a value-added summary of specialist technology data and employs existing expertise and information infrastructure. TIFACLINE provides a quick overview of important parameters annexed with succinct explanations, paying due attention to technology and business dimensions.

The main difference between the national-level and firm-level system is in the application of information. The focus of a national-level system is information support for:

- Planning of R & D
- Resource allocation decisions
- Broad technological trends

- ❑ Technologies that have the potential to be supported
- ❑ Potential technologies for export

At the enterprise level, the orientation is technocommercial information rather than information for national policy support. Enterprise-level monitoring requires more technical details than is necessary for national policy-level decision-making.

The second major issue with regard to a national-level system is to estimate and provide diverse information to a variety of users. The diversity of the monitoring base at national level should be very high since it needs to support science and technology decision makers and corporate users, in addition to various administration ministries. Prior to designing the technology monitoring system at the national level, a comprehensive user-requirement analysis should be conducted. The information required for a national-level system is likely to be available in the public domain, whereas the enterprise-level system will require considerable effort in scanning the information, especially when firm-level initiatives of competing firms are involved. In many of the national-level monitoring systems, the objective has been to provide monitoring services to small and medium-sized enterprises that cannot afford their own monitoring systems and databases.

Regional level

Here again, the models used by both the Asian Pacific Centre for Transfer of Technology (APCTT) and the Latin American Economic System (SELA) are interesting. The APCTT model has particular features that are attractive. The focus of monitoring has been the stimulation of enterprise-level technology transfer through monitoring and dissemination through networking. It clearly shows that an international institution affiliated to the United Nations can effectively work to satisfy enterprise-level needs. The major lessons are:

- ❑ A global regional-level organization has the ability and capacity to facilitate technology transfer (not merely for monitoring) between developing coun-tries as well as between developing and developed countries;
- ❑ Monitoring should be used not as an end in itself, but as a means for regional cooperation;
- ❑ Currently, there is no exclusive agency playing such a role (apart from APCTT) at the global regional level. This implies that more global regional monitoring networks could satisfy a need for monitoring-cum-technology transfer;

- Networking agencies, consultants and firms will create cooperation. This will require comparatively less investment. Networking creates a win-win situation among partners and such an operation can sustain itself through user charges;
- Integrating monitoring, technology fairs (Techmart activities of UNIDO is an example), consulting services and technology transfer helps firms, particularly small or medium-sized enterprises) that have been poorly ser-viced in terms of their technology monitoring requirements, by offering a comprehensive package of initiatives.

Ethics in monitoring

Technology monitoring does not involve unethical or illegal practices. Adhering to good ethics is not only the right thing to do, it pays dividends [4]. Organizations have a responsibility to ensure that their respective technology monitoring does not violate any ethical codes of corporate behaviour. It is important that corporations as well as individual consultants have a code of ethics that applies to issues involving technology monitoring as well as competitive intelligence [4].

The following is a useful guide for individuals involved in technology monitoring, to ensure that intellectual property rights or any ethical norms of behaviour are not violated.

Code of ethics

To continually strive to increase respect and recognition for the profession on local, state and national levels.

To pursue his or her duties with zeal and diligence, while maintaining the highest degree of professionalism and avoiding all unethical practices.

To faithfully adhere to and abide by his or her company's policies, objectives and guidelines.

To comply with all applicable laws.

To accurately disclose all relevant information, including the identity of the professional and his or her organization, prior to all interviews.

To fully respect all requests for confidentiality of information.

To promote and encourage full compliance with these ethical standards within his or her company, with third-party contractors and within the entire profession.

Conclusion

Technology monitoring is indispensable when the aim is to satisfy needs at various levels. Careful attention is required when assessing the needs of various users and designing a monitoring system to meet the specific requirements of users. It is crucial that issues involved in implementation be examined at the design stage.

References

1. B. Gilad, *Business Blindspots: Replacing Your Company's Entrenched and Outdated Myths, Beliefs, and Assumptions with the Realities of Today's Markets*, Probus, Chicago, 1994.
2. B. Bowonder, "Technology Monitoring at the Enterprise Level", meeting on Cooperation in Technology Monitoring in Developing Countries, UNIDO, New Delhi, 22-25 November 1994.
3. D. Tapscott and A. Caston, *Paradigm Shift: The New Promise of Information Technology*, McGraw-Hill, New York, 1993.
4. L. Kahaner, *Competitive Intelligence from Black Ops to Boardrooms: How Businesses Gather, Analyze, and Use Information to Succeed in the Global Marketplace*, Simon & Schuster, New York, 1996.

7. Organizing for technology monitoring

The final topic for consideration is how to organize technology monitoring functions at various levels. Several issues are involved and need to be understood in order for technology monitoring to be utilized to its full potential [1].

Organizing at various levels

Enterprise-level model

A technology monitoring process [2] requires three major elements within an automated environment:

- A point of convergence where diverse pieces of information can be collected from various sources
- A variety of collection points, scanning arrangements and analysis procedures
- A system capable of storing information that will enable easy retrieval and communication

Such a process requires that data indicating trends in technology be collected at various levels and communicated in a simple format to an identified location. A person should be assigned this specific task once the expectations and the responsibilities are clearly defined. The individual identified for such a role should be able to communicate easily with people in technical and commercial fields. The second major functional aspect is analysis of information. The analysis should be done through:

- Upward interaction
- Lateral interaction
- Downward interaction

This will ensure that the information from technology monitoring is effectively collected and assessed, and that the results are utilized. It is also essential for the enterprise to design a system that incorporates appropriate information security measures.

When those aspects are analysed and converted into an organizational arrangement, it means that a technology monitoring system will consist of the following activities or elements:

- ❑ A scanning or information collection system
- ❑ A layer of subject and strategy experts (internal)
- ❑ An embedded ring of functional managers
- ❑ A variety of information sources (internal databases, collection sources, collection centres and on-line databases available world-wide)
- ❑ A top management strategy group that provides direction and uses the results of monitoring
- ❑ A core group that devises strategy for monitoring and analyses the information obtained from scanning

The major external information sources to be monitored for accessing external knowledge should be chosen by the monitoring group. Major sources that may be included are:

- ❑ National R & D institutes
- ❑ Internal R & D units
- ❑ Universities
- ❑ High-technology companies
- ❑ Software technology parts
- ❑ Company product catalogues
- ❑ Trade journals
- ❑ Patents
- ❑ Databank networks
- ❑ Design firms
- ❑ Multilateral agencies
- ❑ Technology monitoring reports from consulting firms

The following are the major responsibilities of the technology monitoring group at the enterprise level:

- ❑ Identifying the strategic focus of technology monitoring activities and required outputs
- ❑ Finalizing the nature of output, frequency and distribution

- Identifying the sources for monitoring
- Forming an inter-functional screening group
- Communicating results of monitoring to top management
- Collecting information from internal sources
- Devising an information storage strategy so that retrieval is easy
- Designing an information security strategy in order for strategic information to be protected
- Training experts with the required competence in the organization
- Identifying information vendors and consultants needed for providing value-added information
- Improving the interface between business strategy formulation and technology monitoring
- Involving functional managers in technology monitoring through lateral and downward communication arrangements

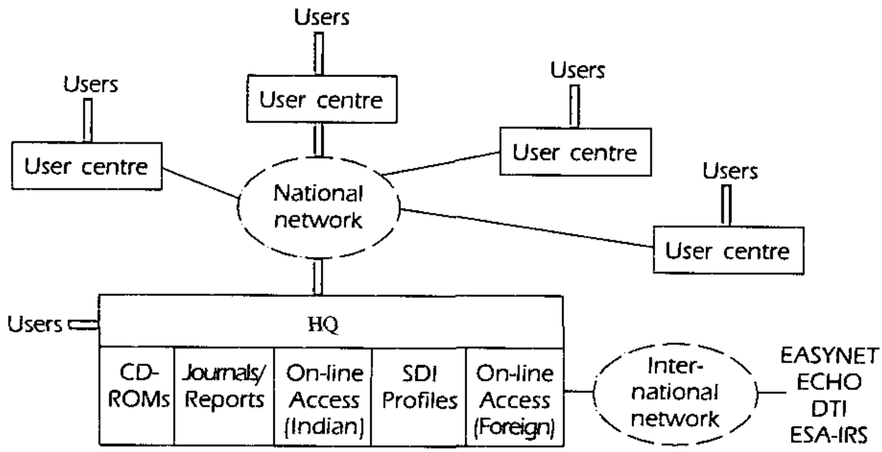
A provisional organizational set-up of an enterprise-level monitoring system is given in chapter 5, figure 34.

The size of the group involved in monitoring will depend on the size and competitive position of the firm and the dynamics of technology. Large firms will require a greater organizational effort, as will firms in highly competitive arenas and those involved in rapidly changing high-technology fields.

National level

At the national level there are two possible structures for monitoring. One option is to have a monitoring and dissemination system coordinated through an APEX industry association. In India such an alternative is being implemented. It is envisaged that the structure will have one central database and state-level access nodes for users. The most difficult task at this level is to design a system that can cater to a wide range of users. Industrial associations would prefer broader data coverage rather than in-depth information on specific sectors. The option available for a national-level monitoring system is depicted in figure 37 below. The organizational configuration presented is based on a structure used by the Confederation of Indian Industry [3]. It is an association of Indian industries that has a membership of 2,600 comprising small, medium-sized and large companies. There is a central office, a number of regional offices and state offices.

Figure 37. Configuration of a national network



Key: SDI: selective dissemination of information

The focus of monitoring at the national level is envisaged as a three-segment system, namely:

- ❑ Monitoring and patent information access
- ❑ Monitoring trends in technology and technology forecasts done by the rest of the world
- ❑ Monitoring R & D outputs and areas of interest of R & D institutions

The monitoring system covers the following industries:

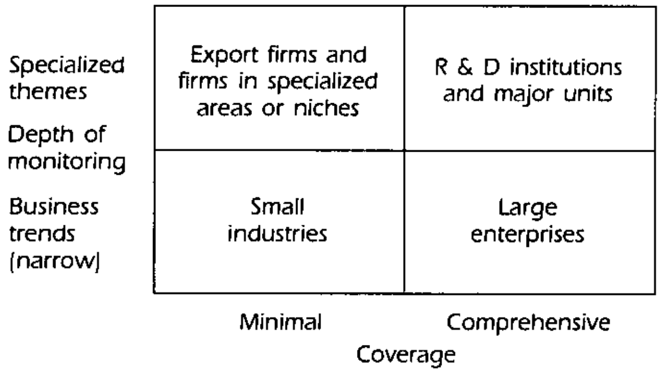
- ❑ Emerging industries
- ❑ Contemporary industries
- ❑ Mature industries

The depth and scope of a national-level technology monitoring system is given in figure 38 below. A large enterprise will need broad business trends and comprehensive coverage of all functional aspects in monitoring. A national-level system will need to support all four types of user requirements.

A national-level monitoring system will have the following elements:

- ❑ CD-ROMs
- ❑ Journals and reports
- ❑ National on-line search service

Figure 38. Scope of monitoring



- ❑ International on-line search service
- ❑ Selective dissemination of information (SDI)
- ❑ Industry monitoring and analysis
- ❑ Internet access

The national network will have a number of regional offices for servicing major industrial centres or user areas. In developing countries, the network will have both computerized document management systems as well as manual industrial-analysis reports. The regional office can provide dial-up service to its members.

The basic issues at this level are likely to be the following:

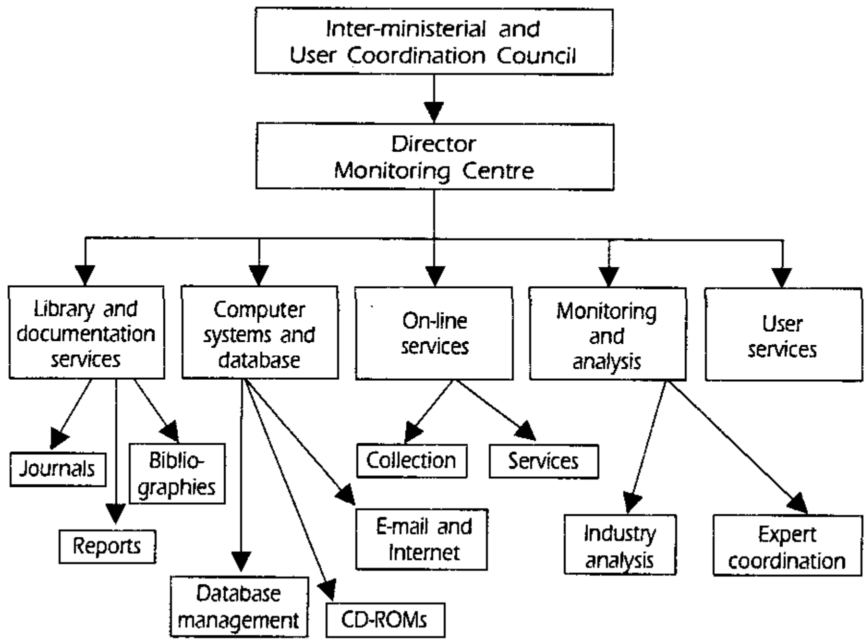
- ❑ Types of industry to be covered for monitoring
- ❑ Output of monitoring
- ❑ Depth of coverage envisaged (patents, abstracts of full-text services)
- ❑ Types of service to be covered (regular, query search, specific client-based reporting)
- ❑ Experts to be used in preparing monitoring reports

The second type of organizational arrangement can be a government-mediated national network. Japan has used such a monitoring network, as described in annex II. Chapter 6 also discusses the structure of TIFACLINE, a national network operating in India. It is possible that a similar structure can be used in countries where infrastructures that support research information are in place. In countries where there is no monitoring support from other organizations, it may be better to have a national-level system. To make it viable, it needs to be a participatory one involving users (firms) and other government departments such as industry, commerce, environment, energy and communications. The monitoring centre should have an advisory or policy coordination body that represents the users and policy makers. The objectives and work plan need to be prepared in a cooperative manner. Two basic criteria that need to be considered before setting up a new organization are:

- Sustainability of operations in the long run
- Selecting areas with economic-growth potential

It is essential to start with a basic-level operation that is sharply focused on a few fields. In the case of small countries, it may be reasonable to start with two or three fields and to subsequently expand the scope of operations. The experience of TIFAC in India shows that firms are willing to pay for monitoring. The envisaged organizational set-up is given in figure 39 below. It is better to use external experts in a given field rather than having a large number of internal experts. Similarly, it may be better to procure specialized reports and to conduct searches for users in identified

Figure 39. Organizational set-up for technology monitoring at the national level



fields or areas of technology. Building up product catalogues and firm-level information is a good starting point. The availability of the Internet is a good opportunity, but information needed for small and medium-sized enterprises is not easily obtained from this source. Understanding specific user-requirements is the most critical aspect in designing a new technology monitoring network. Some important initiatives include:

- Creating awareness among potential users
- Understanding user needs
- Satisfying user needs and building organizational credibility

Global regional level

Designing for a regional-level technology monitoring network is a complex task because of the heterogeneity of nations involved. Asia and the Pacific region has such a network. Five additional global regional networks should be established to serve countries from Africa, Latin America, central Asia, eastern Europe and the Middle East.

Initially, seed-funding may be needed. The APCTT model seems a reasonable one. It can be seen from the annual reports of APCTT that there has been a sharp increase in the revenue for APCTT from client industries. The best approach may be to start these as small networking centres and then to develop them as large global regional databases covering many topics and technologies. Such monitoring networks should also provide technology services that will ensure the networks' viability. No separate structure is envisaged for the global regional monitoring network, since the APCTT model can be replicated. The lessons from the APCTT model are given in chapter 6.

References

1. R. T. Lenz and J. L. Engledow, "Environmental Analysis Units and Strategic Decision Making: A Field Study of Selected Leading Edge Corporations", *Strategic Management Journal*, vol. 7, 1986, pp. 69-89.
2. B. Gilad, *Business Blindspots: Replacing Your Company's Entrenched and Outdated Myths, Beliefs, and Assumptions with the Realities of Today's Markets*, Probus, Chicago, 1994.
3. Technology Information Centre, paper presented at the Meeting on Cooperation in Technology Monitoring, UNIDO, November 1994, New Delhi.

8. Facilitating institutional learning about technology monitoring

This chapter provides insight into the modes in which participating developing countries can use the opportunity to learn about technology monitoring in an effective and structured manner.

Institutional learning

Learning is essential for organizations that are critically dependent on their knowledge of technology and that function in environments where technological change presents serious threats and opportunities [1]. Learning has been defined in many ways, but for present purposes, learning in an organization occurs through the processing of information, when the probability that future actions will lead to improved performance is increased [1].

Learning involves acquiring, distributing, storing and interpreting information. The rapidly changing nature of today's organizational or institutional environment and the urge for learning are largely a consequence of three factors:

- ❑ Increased effectiveness of information technology
- ❑ Expanded knowledge base
- ❑ Increased complexity of a rapidly changing environment

The causal chain [1] that highlights the need for institutional learning is shown in figure 40.

Learning from each other

Institutional learning starts with individual learning [2]. It leads to group learning that in turn leads to organizational or institutional learning, as shown in figure 41.

> *Institutional learning is the ability of an enterprise to observe, assess and act upon stimuli that are either internal or external to the organization in cumulative, interactive and purposeful ways [3].*

Figure 40. Institutional learning cycle

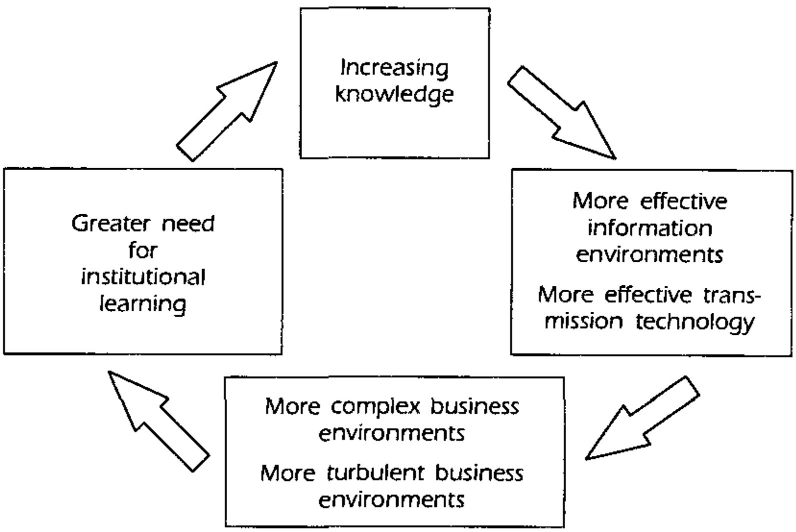
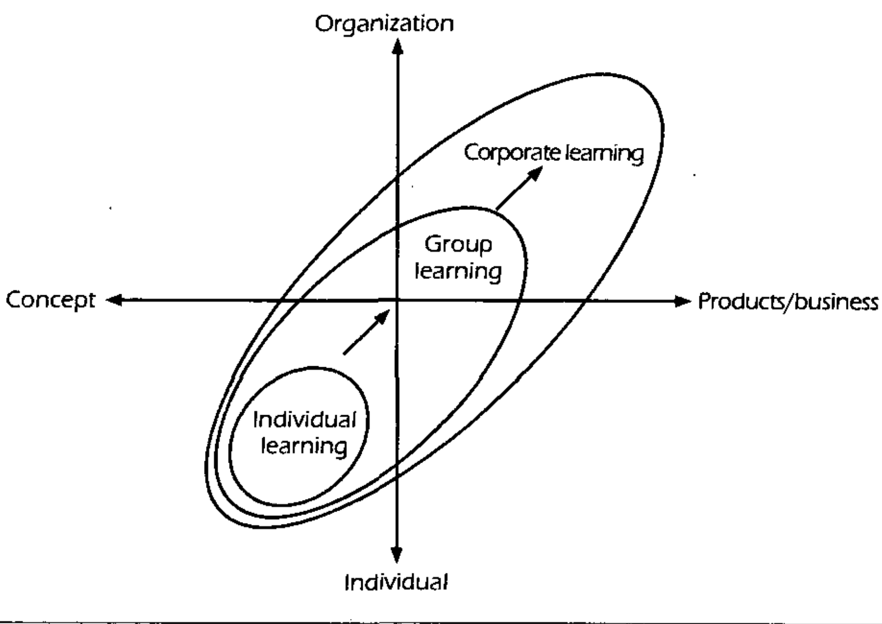


Figure 41. Trajectory of corporate or institutional learning



Institutional learning is more prominent in technology-oriented firms. To meet the challenge of technological acceleration, firms must learn faster and more effectively because the most successful innovative organizations are also high-performance learning systems. To survive and grow, firms are required to do the following:

- Learn in different ways
- "Learn how to learn" under unfamiliar and dynamic conditions
- Learn rapidly
- "Unlearn" outdated practices

This clearly indicates two critical issues:

- Firms need to understand the sustained and complex struggle for survival and growth through learning so as to create a learning system tuned to the global economy;
- Firms need to guide managerial action to improve the learning process in order for organizations to adapt to rapid change.

Technology monitoring is the trigger for institutional learning. It sensitizes executives, it indicates the direction of change and it encourages people to learn and change.

To initiate learning, institutions require monitoring mechanisms that track changes in both internal and external environments. The monitoring mechanisms that can initiate learning in firms include the following:

- Scanning for new technological developments through technical reports and scientific meetings
- Analysing patenting trends
- Forming new joint ventures
- Interacting with consultants and industry experts
- Observing and imitating new ideas and methods
- Test-marking
- Facilitating internal R & D
- Conducting review meetings
- Undertaking competitive surveillance

If the signals from those sources are recognized and understood by an organization, institutional learning can be stimulated and learning cycles produced, resulting in effective institutional actions [3].

Studies on institutional learning have the following implications for facilitating technology monitoring:

- The speed and rigour of institutional learning depends on the level of change that is detected in the external environment. Technology monitoring exercises should let decision makers experience the reality of change;
- Radical and complex forms of institutional learning involve changing the ongoing systems and the underlying norms and values within the organization in substantial ways. Monitoring should trigger change that requires identifying agents of change and opinion leaders, and communicating the messages to them;
- Institutional learning implies active enquiry, memory systems and cumulative action [3]. Firms must find ways to interpret technology signals correctly in order to learn from them. Hence, scanning and monitoring need to be done very effectively otherwise learning is not induced;
- Institutional learning, especially creative learning, requires a receptive organizational culture. This invariably involves radical redefining of learning processes along with problem and answer restructuring, inter-functional cooperation, constructive conflict and a general openness of business processes and decision-making;
- Before institutions can learn something new, members need to "unlearn" what they think they already know [4]. They may have to discover that they should no longer rely on current beliefs and methods. Ideally, technology monitoring facilitates the elimination of obsolete beliefs;
- Technology monitoring should act as an agent for learning from others. Learning from others is the key to change and monitoring should facilitate institutional learning in many ways.

The major challenge is to design systems and procedures that can help institutions to learn new things and let go of old technology concepts.

> "Current beliefs and methods bias information gathering. Signals from one's environment tend to support these beliefs and methods. To obtain dissonant signals, one may have to be proactive. Thus, one should try to turn surprises into question marks, should respond to dissents and warnings as if they have some validity, and should consider whether new ideas are as deserving as one's own."

Source: W. H. Starbuck, "Unlearning Ineffective or Obsolete Technologies", *International Journal of Technology Management*, vol. 11, No. 7/8, 1996, pp. 833-845.

Monitoring and action

Practical knowledge has two major components [5], namely:

- ❑ Tacit knowledge
- ❑ Explicit knowledge

Tacit knowledge consists of embedded routines and is not easily visible and expressible. Explicit knowledge is articulate, formal and systematic. Practical knowledge is a combination of both. Monitoring and action requires:

- ❑ Dialogue, communication and exchange
- ❑ Field action or learning by doing
- ❑ Linking explicit knowledge through monitoring of new knowledge (transfer as well as innovation)

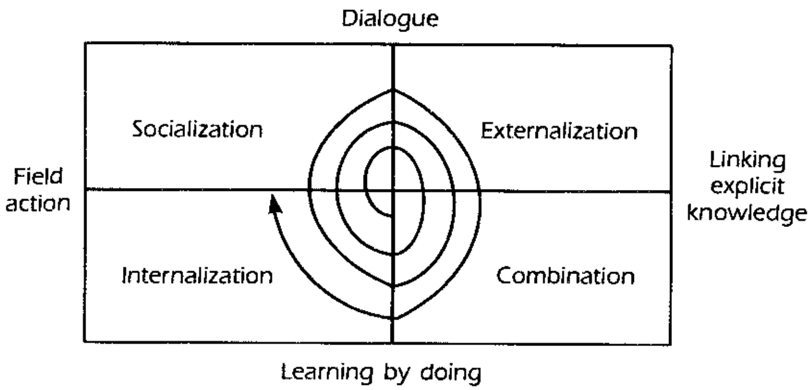
This means that technology monitoring needs to be embedded into other organizational processes, namely:

- ❑ Socialization for increasing creation and utilization of tacit knowledge and its exchange;
- ❑ Internalization of knowledge: transforming from explicit to tacit, through learning by doing. This involves communication, exchange, learning and documentation;
- ❑ Externalization involves converting tacit knowledge into explicit concepts through monitoring, exchange, dialogue and collective reflection;
- ❑ Combination involves the process of systemizing concepts from various individuals and functional departments into knowledge systems. This occurs through exchange and knowledge integration involving documents, meetings, analyses and computerized monitoring networks.

The four modes of interaction are schematically presented in figure 42 below [5].

Monitoring should use all four elements of knowledge creation, given in figure 42, for stimulating organizational action. Without the four processes, knowledge creation and its utilization do not take place. The firm-level imperative should be to combine the four modes so that innovation can be incorporated in the business. The challenge is to link learning and action and to reinforce this process in order to make continuous learning a routine process in institutions. In this way, ordinary institutions become high-performance learning systems.

Figure 42. Learning in institutions



Source: I. Nonaka et al., "A Theory of Organizational Knowledge Creation", *International Journal of Technology Management*, vol. 11, No. 7/8, 1998, pp. 833-845.

Rapid institutional learning

One of the main objectives of the present manual is to encourage institutional learning, especially with respect to elements such as technology transfer, new technology-based ventures, innovation, licensing, joint venturing and joint development, through the use of technology monitoring. This section examines the routes that can lead to rapid institutional learning.

Technology transfer

Technology transfer in general and transnational transfer in particular probably contribute increasingly to productivity growth. Monitoring and dissemination of monitoring results promotes transfer among countries and regions. Technology transfer is as important as domestic innovation, as a means of stimulating industrial growth [6]. Increased monitoring and technology transfer lead to increased industrial growth through learning. Transfer induces learning by doing; however, for this to happen, scanning and monitoring need to become a part of the organizational routine.

Continuous improvements

Continuous improvement of the process is yet another result of institutional learning. Monitoring should lead to the close cooperation of the innovator, the imitator and the entrepreneur; in turn, this should lead to the continued use of innovations in the manufacturing process. Triggering continuous improvements using monitoring is another major way of encouraging innovations at a lesser cost. It requires competence in monitoring signals of change and in interpreting them while filtering spurious signals or noise. Monitoring, continuous improvement procedures and facilitation of continuous learning will need to be linked through organizational systems and routines.

Professional exchanges and international cooperation

Professional exchanges and participation in fairs are two important ways of facilitating learning and implementation. Such interchanges involve monitoring and transfer of tacit knowledge that is not available formally. Professional exchanges between monitoring agencies can facilitate the communication of tacit knowledge—especially when there is scope for the secondment of experts from one region to another. Ideally, this has the potential to become a major component of international cooperation, apart from regional-level technology monitoring.

Exchange of monitoring results

Monitoring exercises carried out in one global region can be disseminated to other regions through any one of the following agencies:

- A regional monitoring network
- A national monitoring network
- An enterprise monitoring network

The operation of regional monitoring networks, along with national and enterprise-level monitoring networks will facilitate learning and result in increased:

- Entrepreneurship
- Joint ventures
- Licensing
- Technology transfer
- Productivity growth
- Technological innovations

Summing up

In a global economy characterized by competition, innovation, alliances, complexity and uncertainty, the only way to reduce business risk is to anticipate change and to facilitate learning processes. To achieve this, monitoring signals of change is the key, as illustrated by Rosenberg [7] in the excerpt below.

> Francis Bacon observed almost 400 years ago that the three great mechanical inventions of printing, gunpowder and the compass "have changed the whole face and state of things throughout the world, the first in literature, the second in warfare and the third in navigation". What Bacon did not observe was that none of these inventions, which so changed the course of history, has originated in Europe although it was from that continent that their worldwide effects began to spread. Rather, these inventions represented successful instances of technology transfer—possibly, in all three cases, from China. It may be seriously argued that, historically, European receptivity to new technologies and the capacity to assimilate them whatever their origin, has been as important as inventiveness itself.
>
> N. Rosenberg [7]

Looking for new ideas and using them in business is the crux of economic growth. Technology monitoring increases receptivity to new technologies when the results are disseminated widely. Advances in information technology and the evolution of the Internet are facilitating this process. Developing countries should take advantage of this opportunity to induce industrial growth, to form strategic alliances and initiate joint ventures. By seizing such opportunities, developing countries could become rapidly integrated into the global economy. Another economic implication of monitoring is the increase in options for development and growth by facilitating networking. Three major driving forces [6] of industrial growth are:

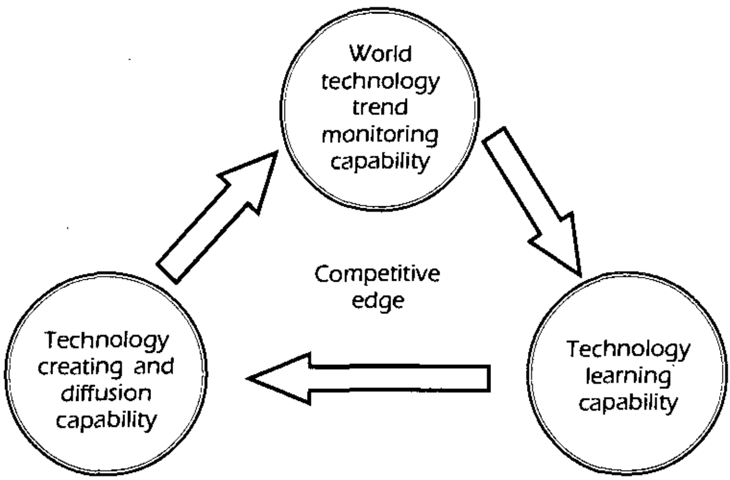
- Entrepreneurship
- Investment in the innovation process
- Technology transfer

Technology monitoring triggers all three and has spillover effects on education, services, trade and industrialization. It is vital to seek new ideas actively; in this, monitoring is an ideal tool. Firms need to institutionalize technology monitoring in order for learning to be induced at individual, group and organizational levels.

Three capabilities [8] needed to generate and sustain competitiveness are:

- Monitoring of trends in technology, worldwide
- Creation and diffusion of technology
- Technological learning as shown in figure 43

Figure 43. Technology monitoring and competitiveness



The elements shown in figure 43 above are overlapping and integrative. The capability of an enterprise or a nation to be competitive depends on its ability to link technology monitoring, learning, creation, transfer, innovation and diffusion in a mutually reinforcing manner.

References

1. G. P. Huber, "Organizational Learning: A Guide for Executives in Technology Critical Organizations", *International Journal of Technology Management*, special publication on unlearning and learning, vol. 11, No. 7/8, 1996, pp. 821-832.
2. T. Murakami and T. Nishiwaki, *Strategy for Creation*, Woodhead, Cambridge, 1991.
3. P. W. Meyers, "Non Linear Learning in Large Technological Organizations", *Research Policy*, vol. 19, 1990, pp. 97-115.
4. W. H. Starbuck, "Unlearning Ineffective or Obsolete Technologies", *International Journal of Technology Management*, special publication on unlearning and learning, vol. 11, No. 7/8, 1996, pp. 725-735.
5. I. Nonaka, H. Takeuchi and K. Umemoto, "A Theory of Organizational Knowledge Creation", *International Journal of Technology Management*, special publication on unlearning and learning, vol. 11, No. 7/8, 1996, pp. 833-845.
6. W. J. Baumol, *Entrepreneurship, Management and the Structure of Payoffs*, MIT, Cambridge, Massachusetts, 1993.
7. N. Rosenberg, *Inside the Black Box: Technology and Economics*, Cambridge University Press, New York, 1982.

Annex I

Sources of monitoring information

The following is a selection of sources that provide useful information on technology monitoring:*

General industry information and economic data

World Development Report
published for the World Bank, Oxford University Press, New York, 1993-, annual.

International Yearbook of Industrial Statistics
UNIDO, Edward Elgar Publishing Limited, United Kingdom of Great Britain and Northern Ireland, 1995-, annual.

International Trade
World Trade Organization, Geneva, 1994-, annual.

World Investment Report
United Nations, New York, 1991-, annual.

Technology and general product information

New Technology Japan
Japan Eternal Trade Organization, Machinery and Technology Department, Tokyo, 1986-, monthly.

Asia Pacific Tech Monitor
Asian and Pacific Centre for Transfer of Technology, New Delhi, bimonthly.

Current Contents
[several subjects] Institute for Scientific Information, Philadelphia, United States of America, weekly.

Design News
[several subjects] Cahners, Boston, United States of America, biweekly.

*This information was accurate as at March 1997.

Industry Week
Penton, Cleveland, weekly.

Digest of Japanese Industry & Technology
Japan Trade & Industry Publicity, Tokyo, -1996, bimonthly.

Techno Japan
Fuji Marketing Research Company, Japan, 1985-, monthly.

Specialized journals targeted at one or two segments

Appliance: Design, Production, Management
Dana Chase Publications, Elmhurst, United States of America, 1969-.

Chemical and Engineering News: "News Edition" of the American Chemical Society
The Society, Easton, Pennyslvania, United States of America, 1942-.

Journal of Electronic Engineering
Dempa Publications, Tokyo, 1974-.

Food Technology
Institute of Food Technologists, Chicago, United States of America, serial.

Genetic Engineering and Biotechnology Monitor
UNIDO, Vienna, irregular serial.

Microelectronics Monitor
UNIDO, Vienna, 1981-, irregular serial.

Advanced Materials & Processes
American Society for Metals, Metals Park, United States of America, 1985-.

Databases

Worldscope
Comline
ABI/Inform
Business Archives
Engineering & Applied Science and Technology
DIALOG
Water lit
Lexis/Nexis
Engineering Index

Annex II

Case studies and country experiences

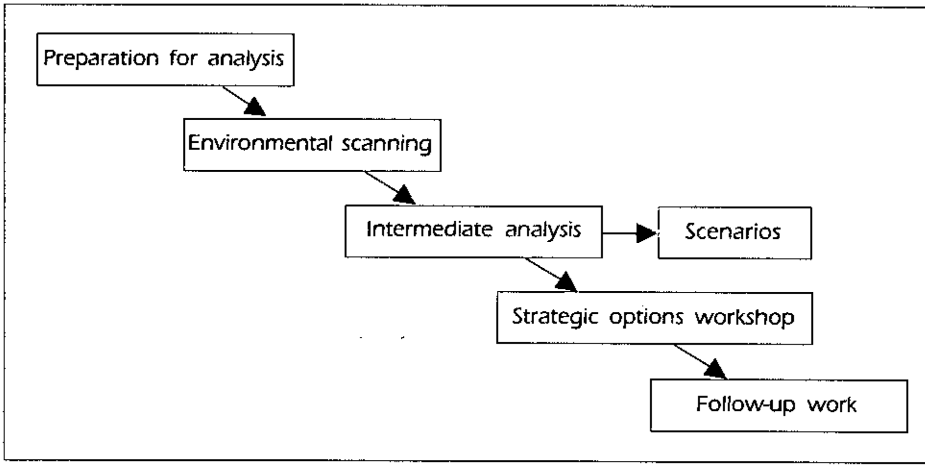
The following case studies focus on technology monitoring in particular countries, namely, Australia, India, Japan, the Netherlands, South Africa and the United Kingdom of Great Britain and Northern Ireland; and two regions: Asia and the Pacific, and Latin America. The regions and countries were chosen based on the availability of information. Non-inclusion does not imply that a technology monitoring system does not exist. Examples are selected to illustrate the varied nature of institutional arrangements used for technology monitoring.

EXPERIENCES AT THE NATIONAL LEVEL

Australia

In Australia, monitoring and forecasting are used in an integrated manner [1]. A critical overview of monitoring and forecasting exercises shows that the earlier approach of preparing deterministic forecasts about the future had a number of shortcomings. Based on the reported work on forecasting, senior decision makers in Australia arrived at certain conclusions, namely:

- ❑ Organizations need efficient and cost-effective ways of dealing with uncertainty and rapid change;
- ❑ The risk of failure is increased if the assumption is that the future will be like the present, or that decisions can be deferred until the environment is better understood;
- ❑ Predictions about the future are seldom 100 per cent correct, but alternative outcomes can be systematically explored;
- ❑ Views about the future can be clarified through systematic exploration and monitoring efforts;
- ❑ Monitoring and techniques of research into future trends can be combined to provide a coherent picture of alternative future environments.



Methodology

A methodology for future studies, known as the Quick Environmental Scanning Technique (QUEST), was developed and used [2]. The QUEST process consisted of a five-step approach:

The preparation stage consisted of a quick scan. It began with initial contact, discussions and subsequent briefing. QUEST was not an exercise in prediction: it helped to explore an array of future options using different assumptions. The environmental scanning and option analysis was done in a workshop mode. The third step was an intermediate analysis that aimed to generate a series of scenarios. They depicted contrasting future environments that corresponded to clusters of trends and events. After scenario development, an interactive workshop was conducted in which each scenario was used as a starting point for identifying and refining strategic options. The process was performed in groups, each working on one scenario. A detailed analysis was then presented. The last step involved selecting the most robust options for further work. Robust options were those which seemed to apply across a range of scenarios. The outputs of QUEST were:

- Identification of options
- Clarification of tasks and responsibilities
- Key ideas for further work

QUEST proved to be a fluid and adaptable approach for technology foresight. The emphasis in this approach was on problem clarification and interactive problem solving through a team approach. It was an approach used in many organizations.

Lessons learned

The Australian experience shows that environmental scanning and scenario building are very useful tools for identifying and refining alternative outcomes. Problem clarification carried out in an interactive mode can bring out new options for action. Such methods help in the creation of a break with the past. More than the results, the team approach of technology foresight enhanced team commitment to the project's implementation.

India

India is one of the developing countries that has an institutional system for technology monitoring. Monitoring has been entrusted to an agency by the name of Technology Information, Forecasting and Assessment Council (TIFAC). This is an autonomous agency coordinated by the Department of Science and Technology, Ministry of Science and Technology, Government of India. The monitoring activities are carried out in three modes.

Methodology

Specialized monitoring studies: Select studies analysing trends in technology were conducted regularly and disseminated. The objective of such studies was to prepare an in-depth analysis of emerging trends. These were conducted by external experts identified by TIFAC. The areas in which monitoring was carried out were determined by the Governing Council that consisted of experts from industry, government, academia, industrial associations and financial institutions.

The studies were carried out at regular intervals, as and when TIFAC perceived the need for such exercises.

Technology vision 2020: Creation of the monitoring studies has stimulated the awareness of decision makers in terms of the need for a strong focus on the future. To address this, TIFAC appointed a number of panels. Two types of panels were used. For highly specialized areas that needed a sharp focus, small task forces were formed. The areas included advanced sensors, surface engineering and waterways, among others. In other areas, where broader participation and consensus was needed, a multidisciplinary panel was constituted for each segment. Here (as in the United Kingdom) the head of the panel was selected from industry in order to sharpen user focus. TIFAC formed ten panels specifically for this purpose. The panels monitored trends in technology and identified action needed in the ten areas. The results were disseminated in three forms, namely:

- A short summary of trends and action imperatives mainly oriented to chief executives and senior decision makers;
- A detailed report consisting of trends, trend analysis and action imperatives focused on operational-level personnel from industries, government and R & D institutions;
- A user-friendly document giving 50 emerging technologies that have great commercial potential. This was prepared mainly to inform industry leaders and opinion makers in industrial associations.

This exercise used the technology monitoring results to give a directional thrust to technology development efforts. The focus was on stimulating technology transfer, technology innovation and rapid industrialization. Monitoring in this case was used as a tool for:

- Exploring future technology options
- Developing future-oriented technology missions for solving specific problems faced by various sectors of the economy

Monitoring facilitated the extension of the technological visions on the part of industrial executives, officials and technology experts.

TIFACLINE

In order to facilitate monitoring activities, TIFAC developed a computerized database, namely TIFACLINE. The objective of the programme was to provide a comprehensive information support system for technology monitoring using existing institutional networks. Networking was achieved through the use of a common data format and data usage protocols. A broad description of the structure of the TIFACLINE network is given in figure 44 below. The structure of a typical TIFACLINE host is illustrated in figure 45.

Lessons learned

The following is an outline of the major lessons learned from the Indian experience:

- *Coordination*: It is important to have a single, nodal organization responsible for the coordination of technology opportunities in developing countries;
- *Understanding user needs*: Monitoring needs to be conducted at various levels, the first level being the actual users of technology information. The second level is highly specific technology-

Figure 44. TIFACLINE network

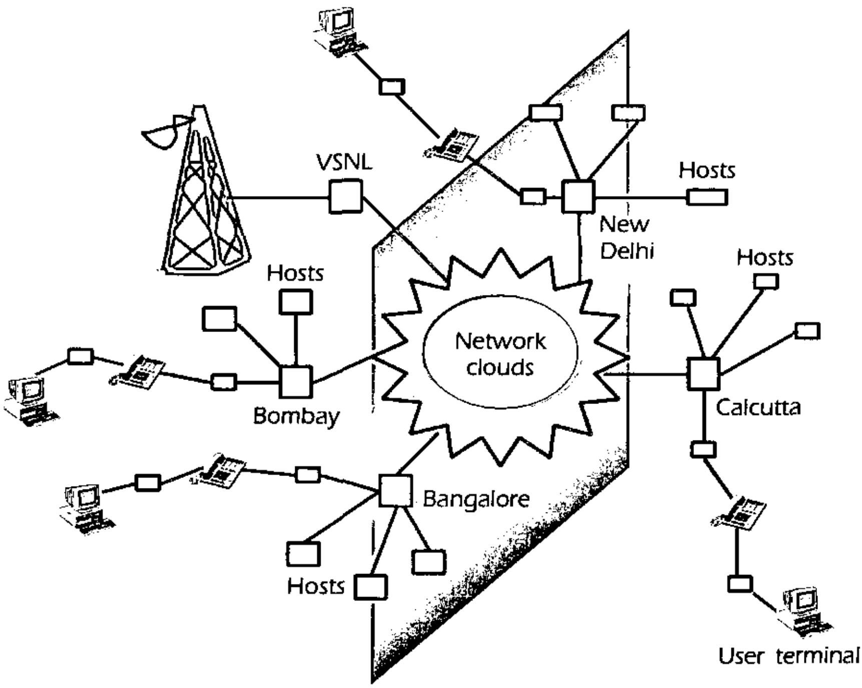
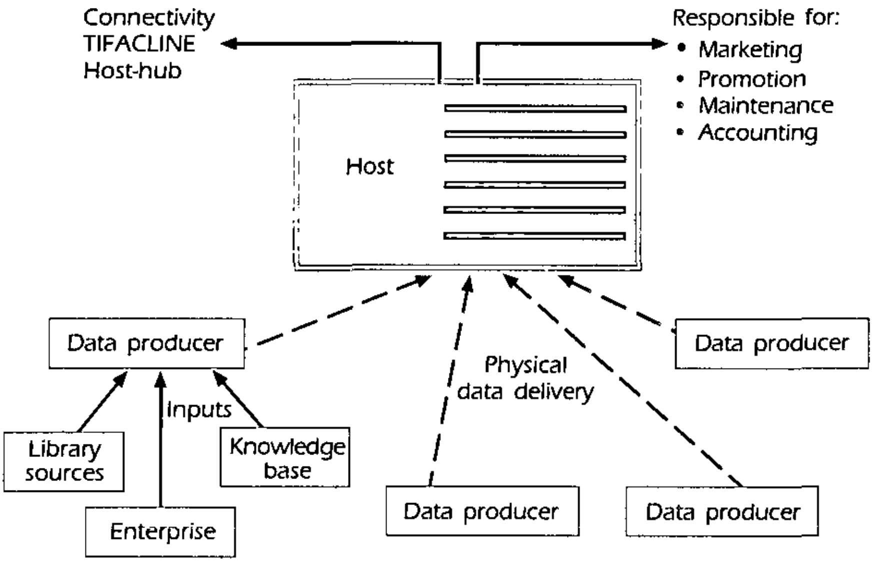


Figure 45. A typical TIFACLINE host



oriented information. The third level is information support needed for sensitizing senior-level decision-making authorities. For each targeted user, the packaging of information should be done appropriately in terms of content, message, focus, depth and frequency;

- *Using existing institutions*: Various types of industries need different types of information. Understanding the specific information requirements of various users needs to be given proper attention before a technology monitoring system can be designed. At the national level, it is better to use existing institutions and their expertise rather than develop a stand-alone system. TIFAC was able to become operational by employing monitoring systems that already existed in other institutions.

Japan

In the Japanese system, monitoring and forecasting form an integrated sequence [3]. Japan is the only country to have carried so many studies on long-term trends in technology in selected areas of interest. The Japanese technology-forecasting system identified the main elements of the emerging "information communication technology" paradigm before any other country. This has enabled Japanese firms to lead the way in exploiting the potential of the newly emerging paradigm in such areas as robotics, computer numerical control machines and flexible manufacturing systems.

The ability to identify areas with growth potential in the form of "independent world technology trend reconnaissance capability" has been the foremost element in the technological capability of building processes in Japanese industries. Foresight in selecting research projects and the systematic evaluation of potential future projects enable Japanese industry to pick winning technologies. Rapid growth is owing to the ability of the Ministry of International Trade and Industry (MITI) to nurture industries with high-growth potential by means of technology monitoring and applying forecasting techniques. The approach of Japanese firms appears to be motivated by the Schumpeterian perspective that competition in the form of new products and processes is the real engine of growth. Schumpeterian efficiency in terms of its effects on the pace and direction of technological change has led to Japan's rapid growth in selected sectors.

The origin of technology monitoring and forecasting in Japan can be traced back to the 1960s when MITI started preparing long-term visions of the future in order to disseminate information on the potential of industries over the ensuing decade. Monitoring trends in technology was used by MITI for assessing the status of indigenous technologies and for identifying new industries with a high-growth potential. Technology monitoring and forecasting was therefore used in the early 1970s to identify technologies upon which Japan should concentrate. Based on the information collected, MITI identified thrust areas for every subsequent decade. In the 1970s, electronic industries were identified as the focus for the decade. In the 1980s, knowledge-intensive industries were identified as the thrust area. Technology monitoring and forecasting exercises continue to be carried out in Japan at various levels.

Technology monitoring and forecasting at the national level

Japan was one of the first countries in the world to carry out technology-forecasting exercises at the national level in order to facilitate long-range policy coordination. Long-range forecasts are carried out by the Science and Technology Agency which reports directly to the Prime Minister's Office. The first technology forecasting survey was carried out in 1970 and 1971. The Japanese exhibited exceptional ability with regard to long-range forecasting and "picking the winners" long before others. The Institute for Future Technology, which was under the Science and Technology Agency,* constituted the Planning Bureau for forecasting exercises or surveys.

The Planning Bureau was in charge of the technology forecasting exercises. It formed an ad hoc committee for the technology forecasting study consisting of experts and specialized subcommittees. Based on the advice of this committee and the subcommittees, the Planning Bureau prepared a questionnaire in each specialized field. The Delphi technique was used in each of the surveys conducted. The fourth survey was conducted in 1988 and covered the period from 1988 to 2015. The fifth survey was done in 1993 and 1994.

Each survey was based on the comprehensive monitoring of trends. The Science and Technology Agency disseminated widely the results of the forecasting study to policy planners, industries, research institutions and academics. The fields covered in the fourth technology-forecasting survey, carried out by the Institute for Future Technology, were information, electronics and software; substances, materials and processing; production and labour; energy; mineral and water resources; marine science; earth science; agriculture, forestry and fisheries; outer space; health and medical care; consumer lifestyles, education and culture; urbanization and construction; environment and safety; transportation; and life sciences.

*This was the case in early 1997.

The strength of the Japanese approach was vested in its interdisciplinary approach, the regular application of the technique, the systematic manner in which the studies were planned, the comprehensiveness of the questionnaire administered and the wide dissemination of the results. The Science and Technology Agency acted as a major facilitator of the survey.

Monitoring and the results of technology forecasting obtained by the Science and Technology Agency have been used to identify projects for the promotion of Exploratory Research for Advanced Technology (ERATO) [4]. The aim of ERATO is to maximize researchers' creative talents for developing innovative technologies for the twenty-first century. The 14 interdisciplinary and long-term projects being implemented by ERATO are ultra-fine particles; amorphous compounds; fine polymers; perfect crystals; bioholonics; bio-information transfer; super bugs; nano mechanisms; quantum magneto flux logic; molecular dynamics assembly; biophoton; terahertz; morphogene; and molecular architecture.

The strength of the national forecasting effort is in its ability to link technology monitoring and forecasting exercises and to identify future-oriented projects that have application in many segments through comprehensive institutional arrangements. Another linkage of monitoring and forecasting occurs through the Japan Science and Technology Corporation, Information Center for Science and Technology (JICST). This operates under the Science and Technology Agency and provides technology information on areas selected for their future potential to private industries and research institutes by means of their on-line data service, Japan Online Information System (JOIS). Strong linkage between technology monitoring and forecasting, long-term planning, projects selection and technology information support help Japanese organizations to plan for the future.

Technology monitoring and forecasting at the industrial level

The various ministries perform detailed technology monitoring and long-term technology forecasts. The responsibility to bring research and development closer to the stage of industrial application has traditionally rested with MITI and the branch responsible for R & D coordination, the Agency of Industrial Science and Technology (AIST). MITI integrates the forecasts prepared by the Institute for Future Technology (mentioned previously) and AIST studies along with the long-range vision information prepared by the respective industrial bureaux of MITI. During the 1980s, two policy documents were prepared by MITI, namely:

- "The Vision of MITI Policies in the 1980s"
- "Towards New Research and Development for the 1990s"

These were integrated to create a long-term research programme, called Basic Technology for Future Industries. This became the basis for a directional thrust for technology development. New materials, biotechnology and new electronic devices were identified as long-term thrust areas. The objective of this project was to monitor trends in technology and to develop new basic technologies essential to the establishment of new industries expected to flourish in the 1990s. These are shown in table 13.

The arrangements prevalent in the 1980s were such that MITI played a very active role in monitoring and formulating projects based on technology-forecasting exercises. Only selected firms were involved in the implementation. This arrangement has changed and currently MITI is more involved with coordinating the interaction of firms and research institutions. Table 14 gives a select list of projects under operation in the 1990s.

Table 13. Technology projects for future industries in Japan

Project	*Objective*
High performance materials	To develop engineering ceramics that are hard and non-rusting
Synthetic membranes	To develop new membranes that can separate gases or liquids
Synthetic metals	To develop polymers that are lightweight, corrosion-resistant and have electric conductivity
High performance plastic	High strength materials with excellent elasticity and electric insulation
Advanced alloys with controlled crystalline structures	Alloys with high performance through single crystallization and grain refining
Advanced composite materials	Lighter, stronger and hard materials
Photoactive materials	For the development of optical devices
Bioreactors	Biochemical reactors using micro-organisms or enzymes
Large-scale cell cultivation	Developing large-scale cultivation through submerged culture
Utilizing recombinant DNA	Developing methods for manufacturing hormones, enzymes and bulk chemicals
Superlattice devices	To develop devices with extremely fine structures using new electronic effects
Three-dimensional ICs	To construct the three-dimensional arrangement of active elements by alternately stacking semiconductor and insulating layers
Integrated circuits for extreme conditions	To develop fortified, highly reliable ICs that can withstand high energy irradiation, high temperatures, mechanical vibration and shock
Bio-electronic devices	To use new functional devices for future computer elements, such as neural networks and bio-elements

Source: B. Bowonder and T. Miyake, "Technology Forecasting in Japan", *Futures*, September 1993, pp. 757-777.

Table 14. Current R & D projects sponsored by MITI: selected examples

Project	*Objective*
New information processing technology (renamed and reformulated in 1992 as the Real World Computing Programme)	To establish the basis for flexible and advanced information technologies for the advanced information society in the twenty-first century
Super-smart vehicle system	To develop an automotive traffic system and improve technology
Micromachines	To develop micromachines composed of microscopic functional elements performing work independently
Human interface	To vitalize the modules commanding the various functions of information-processing equipment using the human interface
New software structural model	To introduce cooperative modules that have a human-like cooperative ability
Ceramic gas turbine project	To develop ceramic gas turbine engines and other supporting elements by 1997
Fuzzy logic	To develop technology systems with capabilities similar to those of human beings
Intelligent manufacturing systems	To develop and integrate advanced production systems with the entire manufacturing process
Nanotechnology	To develop atom-level manipulation and atomic rule-processing technologies
Non-linear optic materials	To develop non-linear optic materials for optical communication and optical amplification
Carbohydrate remodelling	To develop a new carbohydrate synthesis technology and new carbohydrate combination technologies
Three-dimensional systems	To develop systems capable of non-destructive testing of three dimensional defects in composite materials
High-temperature superconducting materials	To introduce superconductive materials and superconductor elements that make possible the use of high-temperature superconducting materials
Twenty-first century housing development	To design and construct systems for living to suit individual needs
Ultra-small robots	To invent ultra-small robots that can move freely within the body of a human or an animal and examine by remote operation

Source: B. Bowonder and T. Miyake, "Technology Forecasting in Japan", *Futures*, September 1993, pp. 757-777:

- Comprehensive monitoring and integrated planning of forecasts and linking all phases of innovation, starting from idea generation, design, engineering, fabrication, pilot production and evaluation in a concurrent manner;
- Involvement of industry, universities, government and research institutions, in the process of forecasting, planning and implementation. For example, MITI has initiated a new project on high-temperature superconductors. In this project, a large number of agencies have been actively involved. The major strength of the

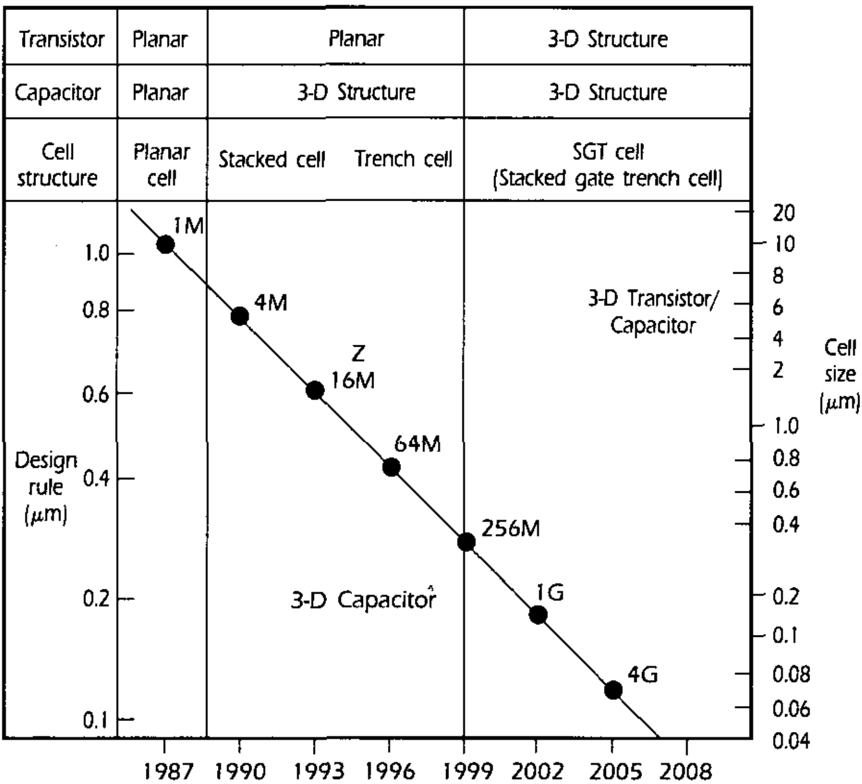
MITI approach is that it involves firms at the project conceptualization stage. MITI also undertakes a detailed evaluation based on the comprehensive technology monitoring of trends.

Japanese technology monitoring and forecasting by groups, associations and research institutes

The third level at which technology monitoring and forecasting is performed in Japan is in groups or by industry associations. For example, four Japanese car manufacturers, including Toyota, Nissan, Mazda and 11 electronics firms have formed a study group on next-generation road transportation. The study group has prepared forecasts and will develop a plan for road transportation covering the following aspects:

- ❑ Automatic driving of cars
- ❑ Automatic control of distance between cars

Figure 46. Future trends in Dynamic Random Access Memory development



- The development of a hybrid engine
- Improvement of the structure of roads

The New Metal Association has carried out a detailed monitoring and forecasting study on the status of room-temperature superconductors. The forecasting study covered two aspects. The first section dealt with the potential application of high-temperature superconduction oxide as a core technology. The second section analysed technology needed for establishing applied systems and breakthroughs needed for industrial application of high-temperature superconducting oxides. The study also identified the following core technologies to be realized rapidly:

- High-purification technology for superconducting materials
- Testing and evaluation of superconducting materials
- Cryogenics
- Quench detection technology
- Magnetic shielding technology

The strength of the monitoring and forecasting exercise is shown in the identification of basic technologies that support the development of room-temperature superconducting.

The Electronic Industries Association of Japan has prepared a study, "Audio Visual Life in 2000", on consumer electronics in the 1990s. Current audio-visual technology will change to audio communication and entertainment technology. Similarly, the Japan Information Processing Development Center (JIPDEC) and the Institute for New Generation Computer Technology (ICOT) have jointly started a centre for studying the utilization of artificial intelligence systems, called the Artificial Intelligence Promotion Centre. The centre is organized as an independent group funded by industries, universities and research institutes.

Technology monitoring and forecasting at the enterprise level

Apart from technology monitoring and forecasting efforts at the three levels (as mentioned, government, industrial associations and research institutions), monitoring at enterprise level and forecasting exercises are carried out for realizing future-oriented projects. A select list of futuristic technologies, known as "new technologies", "next generation systems" or "advanced systems", planned by selected Japanese firms are given in table 15. For example, Japanese firms are developing 4000 MB chips. Toshiba, Fujitsu, NEC, Hitachi and Mitsubishi are planning 1024 MB and 4000 MB Dynamic Random Access Memory (DRAM) chips, as shown in figure 46. Technology monitoring and forecasting exercises

Table 15. Technology forecasting at the enterprise level in Japan

Technology	*Enterprise*
4000 MB chips	Toshiba, Hitachi and NEC
Next-generation cordless telephones (personal mobile communication terminals, pocket telephone, wrist-watch telephone, electronic notebook)	Aquarius
Geoplane: 90-ton heavy passenger aircraft moving in underground tubes at 300 km/h	Fujita Corporation
Next-generation manufacturing systems: CAD/expert systems/robots/neural computers enabling creative product development and production	Hitachi Ltd.
Intelligent electric locomotives	Japan Railway Freight Co.
Next-generation subway coaches	Kawasaki Heavy Industries Ltd.
Next-generation traffic signal communication system	Japan Railways
Next-generation machinable ceramics	Mitsui Mining Co.
Next-generation machine tools	Fanuc Ltd.
New-generation electric batteries with long life, light weight and high energy density	Yuasa, Nippon, Matsushita, Farukawa
Twenty-first century ships: energy-saving ships, techno superliners, super-high-speed ships	Mitsubishi Heavy Industries
Next-generation pipeless chemical plants: pipeless reaction mixing unit with high product-manufacturing flexibility	Tokyo Engineering Corp., Nippon Kayaku
Diamond film transistors	Sumitomo Electric
Optical glass for next-generation devices	Suita Optical Glass
Virtual reality systems: virtual organisms with autonomous decision-making capacity	Fujitsu, Dai Nippon and Intel Japan
Virtual digital interactive video	Tokyo Electric
Virtual 3-D power systems	NEC, Fujitsu, IHI
Tele-operated robots	Matsushita Electric
Virtual space decision support system	NHK
Virtual studio	Mitsubishi Heavy Industries
Virtual flight simulator	ATR Communication
Virtual reality teleconferencing system	Systems Research Laboratory

Source: B. Bowonder and T. Miyake, "Technology Forecasting in Japan", *Futures*, September 1993, pp. 757-777.

carried out at the enterprise level and linked to detailed technology development plans for the future have been important elements of the process in Japan. Japanese firms excel in competence-building and organizational learning processes because they have a clear view of strategic goals for the future. This clarity is the fruit of comprehensive monitoring efforts.

Lessons learned

Uncertainty and inappropriateness are the two major reasons for the institutional failure of innovation systems. To reduce the impact of such problems, the Government of Japan, industrial associations, research institutions and firms have been able to successfully integrate technology and its application into the following sequence: scanning, monitoring, forecasting, planning, development and commercialization.

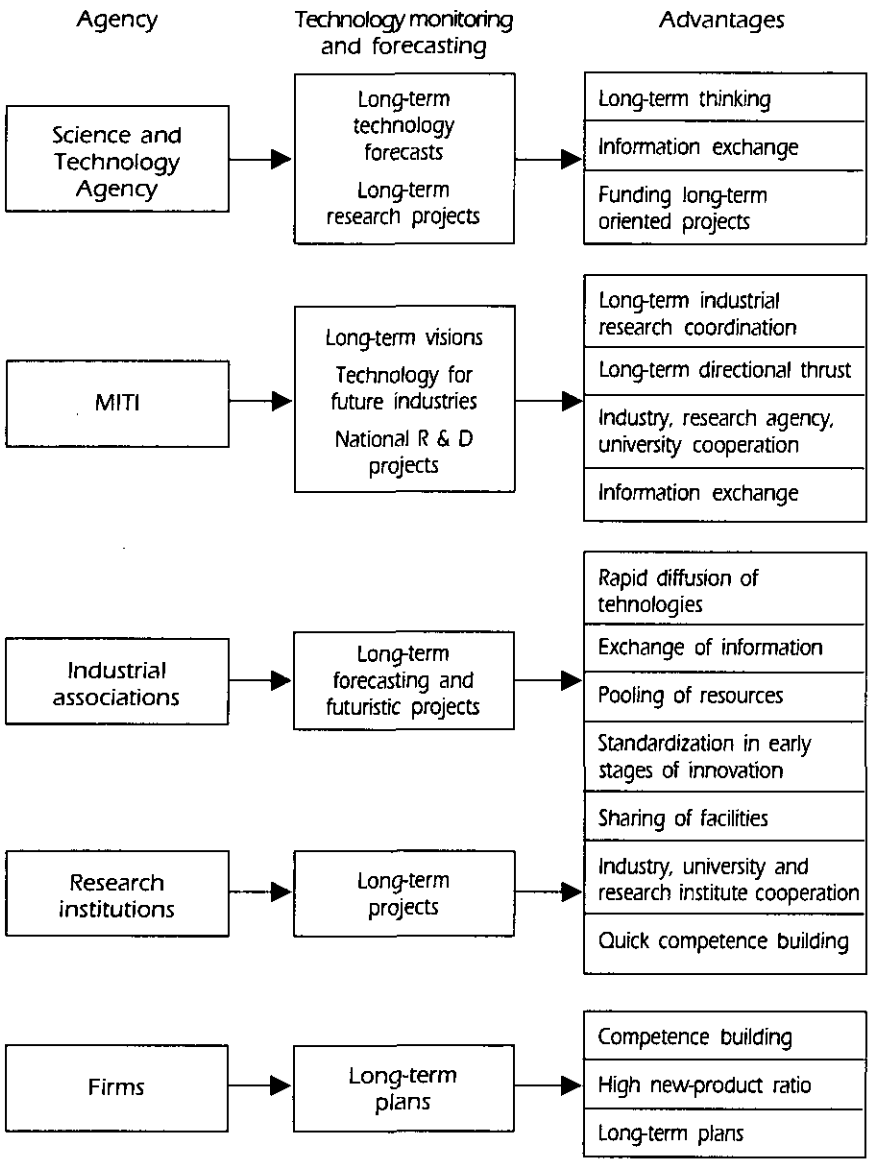
Japanese firms have become more innovative and are aggressively pursuing long-term technological goals, through both individual efforts and cooperative arrangements. Japanese Ministries, various industrial associations, research institutions and firms have been intensively involved in long-term technology monitoring, forecasting and planning technological developments with the active support of "long-term visions". These are summarized in figure 47 below, with the concomitant advantages. Japanese efforts for creating and sustaining competitiveness in selected areas rely heavily on monitoring trends, future studies and closely linking futuristic concepts and current technology-development efforts. Japanese firms are also intensively involved in developing concepts, products and processes to be used in the twenty-first century.

The most striking features of the Japanese technology monitoring, forecasting and development sequence are:

- ❑ Close linking of scanning, monitoring, forecasting, planning and development;
- ❑ Strong involvement of industrial associations in technology monitoring and forecasting;
- ❑ Identification of three or four areas for achieving technological superiority based on trend monitoring;
- ❑ Ability to identify generic projects with future potential through greater clarity of vision of technology trajectories;
- ❑ Strong exchange of information and strategic alliances for the rapid development of competence, within enterprises and between research institutes and firms;
- ❑ Emerging technological trends are continuously monitored, new projects are developed and existing projects updated on a regular basis;
- ❑ Core competencies are extended continuously (microminiaturization, automation and material processing).

Many Japanese organizations use technology monitoring and forecasting on a continuous basis and link it meticulously with technology development efforts for creating and sustaining superiority in the identified areas. Monitoring and forecasting is used in an integrated manner for looking ahead and for decision-making that pertains to technology.

Figure 47. The five-level system of technology monitoring in Japan



The Netherlands

In the Netherlands, where the Ministry of Economic Affairs coordinated the programme, the approach to monitoring was termed "foresight". It was recognized that technology was a key factor in the economic performance of a country, thus it was decided that "foresight studies", whose aim is to identify emerging technologies, warranted more attention. The foresight studies programme had the following three broad objectives:

- To generate information on strategic technology trends;
- To provide small and medium-sized enterprises with up-to-date information about possibilities for applying new technologies;
- To stimulate the creation of networks among actors involved in a defined area of technology in industry, research and the educational system.

> "A small country cannot be a winner in all areas of technology and restricted budgets have to be allocated as effectively as possible. Therefore we find it important to be more active in our technology policy and to become more capable of weighing the different proposals which are put forward to us by the market and by technological practitioners. So the foresight programme has to contribute selection and priority setting in technology policy."

Source: Government of the Netherlands, Ministry of Economic Affairs, "Technology Foresight Studies", The Hague, 1994.

Methodology

With technology becoming a significant strategic factor in the economic growth and trade competitiveness of a country, foresight studies were carried out to identify technologies likely to become important. The programme started as an experiment by the Ministry of Economic Affairs, and has now become an integrated part of the technology policy process in the Netherlands [5]. The principal aim was the generation of information for strategic technology policy.

The "foresight" programme included drawing up a list of prioritized technologies, undertaking an in-depth analysis of a limited number of areas of technology on this list and implementing the outcome of the analysis.

The first step was to draw up a list of experts from:

- The Ministry of Economic Affairs
- Big industries
- Small industries
- The service sector
- Research institutions

On the basis of information obtained from the interaction of these experts, a shortlist of 15 technologies was drawn up. Six criteria were used for shortlisting, namely:

- ❑ Maturity: technology should be proven or it should have passed all the technological hurdles;
- ❑ Multidisciplinarity: technology should involve several disciplines;
- ❑ Potential for wide application: technology should have wide-ranging applications within the next five to ten years;
- ❑ Growth stimulation: application will spur economic growth in a wide range of sectors;
- ❑ Potentiality for networking and ease of commercial realization: parties representing the whole innovation chain can be interlinked;
- ❑ Relevance to small and medium producers and users: applicability of innovation for small and medium-sized enterprises;

In order to pinpoint two or three technologies for an in-depth analysis, the expert group was asked to judge 15 technologies, based upon the selection criteria given above. This was done in four steps:

Step 1: Various sector organizations and cooperating Ministries were consulted in order to exchange information and to gain their commitment to the foresight process;

Step 2: An in-depth analysis of the selected technologies using the above six criteria was carried out by a consultancy firm. The consultancy mapped different players and compared the status in the Netherlands vis-à-vis other countries. The aim of the in-depth analysis was to identify bottlenecks and opportunities in order to indicate which strategic capacities were needed to overcome these bottlenecks and to optimize the identified opportunities in the technology infrastructure, in the formation of networks and in the diffusion of technology;

Step 3: This step involved presenting the results of the study to a representative group consisting of participants from industry, technology infrastructure, service sectors and industrial organizations. The objective of the interaction was to:

- ❑ Inform the relevant stakeholders
- ❑ Test the results
- ❑ Formulate activities to overcome bottlenecks

- Seize opportunities to advance the areas of technology identified or under discussion

Step 4: This step involved implementing the results. Based on the studies and the conference discussions, follow-up activities were identified and initiated by the Government.

A crucial factor in managing the foresight process was supervision. Each study was supervised by a committee consisting of 8 to 10 representatives of the various interest groups, such as enterprises involved in the production and use of technology, research institutions, technical universities and colleges. The entire process was coordinated by a high-level steering committee consisting of the directors of concerned ministries, two external advisers, the Chairman of the forum of top managers from larger industrial firms, professors and a member of the Board of Directors of the Netherlands Organisation for Applied Scientific Research.

Results

Six generic technologies were identified:

- Mechatronics
- Adhesives technology
- Chip cards
- Matrix composites
- Signal processing
- Separation technology

Lessons learned

The Ministry found the process of great value. Technology foresight studies used technology monitoring to identify thrust areas based on growth potential. The entire process demanded a great deal of effort in terms of coordination, consultation, supervision and communication of results. In turn, a significant degree of involvement was required on the part of diverse divisions of the Ministry, agencies and industries. There needed to be a strong interest as well as commitment of the diverse stakeholders. In this case, senior decision makers were convinced that technology foresight studies are an important tool in economic strategy.

A follow-up mechanism is also important if results are to be translated into action. This requires the commitment of intermediaries and financial institutions. The most important aspect is that the process of monitoring and the results of foresight studies are integrated with technology policy planning and implementation. One of the major goals of foresight is to stimulate innovations in small and medium-sized enterprises. The "foresight" programme in the Netherlands was able to achieve the following four major goals:

- The generation of information on trends in technology for technology policy action;
- The dissemination of information on emerging technological possibilities to small and medium-sized enterprises;
- The stimulation and creation of a network of major factors in the innovation chain;
- The creation of a consensus on emerging technological trends through an interactive process.

The experience of the Netherlands indicates that it is possible to create a technology vision by bringing together different stakeholders and creating a commitment. The exercise in forecasting is in essence a technology scanning, monitoring and dissemination system with multiple-party involvement. The special emphasis on the involvement of small and medium-sized enterprises is noteworthy with regard to this country experience.

South Africa

In the 1980s, technology choice and technology monitoring were not national priorities. Today, however, formal technology monitoring is becoming a part of business planning in South Africa [6]. Such activities are located across a variety of academic institutions, state-owned corporations and commercial enterprises [7]. The South African experience is presented under the following sub-headings:

- Infrastructure for monitoring
- Locally-developed tools for technology monitoring
- A case study
- Lessons learned from the South African experience

Infrastructure for monitoring

South Africa has an extensively-linked library network, incorporating books as well as national and international journals. To a limited extent, it also has international linkages. Networking allows technology specialists and other users to access information throughout the country and the world.

A number of technology-specific databases have been developed in South Africa; for example, Waterlit is a database on water-related technology. It is available on network as well as on CD-ROM, has been benchmarked internationally and found to be of a high standard. In addition, databases on a variety of topics have been developed locally.

A number of commercial groups emerged that were able to provide focused monitoring services. The emergence of such groups has facilitated an increased awareness about the need for databases. Some of the technology-specific databases accessible nationally are:

- Waterlit: water technology
- Infopak: information technology
- Quantarch: building technology

Apart from this, international access to technology information is provided through Worldnet gateway which provides a single interface to access international databases as well as Internet access. A private sector company has developed a software tool that allows information to be updated on specific technologies and technology monitoring in a very effective manner.

The Institute for Futures Research is based at the University of Stellenbosch. It provides a number of services of particular significance to the world of technology. The institute acts as a facilitator for managers and technology experts interested in networking and whose focus is on issues relating to forecasting, monitoring and management. A wide array of technologies and issues in technology management are monitored extensively. This information is compiled and provided to members on an annual basis, and technology updates are provided at regular intervals.

Locally-developed tools for monitoring technology

South Africa has successfully developed search engines and database systems for technology monitoring. They are used in PC systems, mainframe systems or CD-ROMs. Professor Van Wyk of the University of Cape Town has developed an approach called the Skyway Theory of Technology. This enables analysis and technology monitoring. By extension, the approach makes it possible to provide managers with important information regarding diverse technologies and their impact on the business environment. This in turn optimizes managers' decisions. The Skyway Theory of Technology classifies technology in terms of a nine-cell grid as shown in table 16 below.

Use of locally developed tools has helped South Africa in the rapid diffusion of technology monitoring.

Case study of technology monitoring in South Africa

A large, integrated transport company approached a science council from South Africa, requesting a proposal on the scanning and monitoring of technology. The scanning process was independently initiated by the trans-

Table 16. Expanded 9-cell grid for technology monitoring

Classes of technological artifacts		*Structural*		*Performance*			
		Size	*Complexity*	*Efficiency*	*Capacity*	*Density*	*Accuracy*
Manipulators of matter	Processor						
	Transporter						
	Store						
Manipulators of energy	Processor						
	Transporter						
Manipulators of information	Store						
	Processor						
	Transporter						

Store

port company as a prelude to the detailed monitoring study. The company's senior management realized that the use of advanced technology by competitors could dramatically affect markets and that the use of advanced technology by themselves could yield a competitive advantage. The basic objective was to ensure that opportunities would not be missed as a result of technological advances. A number of technologies were selected that might have been of interest to their business. A request was made that they be scanned with the following focus:

- To establish current capability and future potential
- To analyse the potential effects such technologies may have on their business environment

The technologies selected were:

- Technologies that utilize coal, including the production of synthetic fuel and electricity generation
- Superconducting technology
- Fuel cells

- Advanced batteries
- Logistics

The technology scanning and monitoring brief was given to technical experts who had access to information sources as well as key people in the client organization. Experts, together with the executives, developed the technology monitoring reports in each of the technology areas. The first round of reports were viewed by the client organization as being technologically complex. A number of iterations were passed to ensure that results were communicated. Technology monitoring was effective in sensitizing the corporate decision makers.

Lessons learned

The six areas listed below represent the significant lessons learned:

- *Organizational readiness*: Senior management in the client organization needs to visibly support technology monitoring efforts and to participate in actions relating to organizational assimilation, utilization and dissemination of the monitoring results;
- *Communication barriers*: A concept such as technology monitoring might mean different things to different people in an organization. It is therefore essential that key concepts and terms be defined and clarified in under-standable and non-academic language. A major determinant for the success of monitoring efforts is the elimination of communication barriers through simple and user-friendly communication;
- *Need assessment*: The experience showed that the technology monitoring needs of management differ significantly across the levels. The South African experience clearly demonstrated that monitoring is needed at three levels and that the information requirements of such segments were distinctly different. The three categories identified are:

    Strategic needs at the executive level are focused on the long-term future of the total business and technologies affecting this level;

    Operational needs of middle management at the business level, i.e. those responsible for making decisions regarding purchase of technology need to take into account the potential value of present investments;

Maintenance needs, focusing on the people responsible for managing and maintaining technology that is acquired in a cost-effective manner;

- *User-friendly results*: Availability of technical experts and provision of access to technological databases does not necessarily result in effective technology monitoring. Technical experts can provide an indication of the technology that needs to be monitored but "wizards" who are capable of viewing events in terms of a systemic approach and who are able to relate the result to the context are needed. An ability to link across disciplines and to relate technology-business interactions is also needed. To be effective, monitoring needs to employ simple terms and user-friendly presentations;
- *Multiple perspectives*: There are significant differences in the points of view of technology suppliers and buyers. Suppliers usually need to focus on the status and trends in cutting-edge technology, whereas buyers are more con-cerned with system applications and functionality;
- *Organization learning*: A learning process was involved for both the technology monitoring firm and the user firm. Creating a joint vocabulary, a communication system and a mutual understanding of needs are factors required to make technology monitoring successful.

> "Technology foresight is a systematic means of assessing those scientific and technological developments which could have a strong impact on industrial competitiveness, wealth creation and quality of life."

Source: L. Georghiou, "The UK Technology Foresight Experience", *Futures*, vol. 28, No. 4, 1996, pp. 359-377.

United Kingdom

The United Kingdom developed "Technology Foresight" as a national instrument of technology policy during the first half of the 1990s.

The need for a systematic approach excludes the normal political and bureaucratic mechanisms by which technology priorities are decided [8].

The main motivation for technology foresight was the emerging competitive context. The increasingly competitive nature of the international economy, and associated global structural changes have led policy makers in industrialized countries towards a renewed emphasis on innovation as an instrument of industrial policy. The technology foresight programme of the United Kingdom was announced in 1993 in a White Paper on science and technology. The general aims of the programme were:

- To forge a new working partnership between those scientists and industrialists in a position to assess emerging market opportunities and trends in technology trends;
- To make informed decisions on the balance and direction of publicly-funded science and technology.

Methodology

The purpose of the programme was to help business people, engineers and scientists become better informed about each other's efforts. The idea was to bring these communities closer through networking, thereby facilitating the identification of emerging opportunities in markets and new technologies. The results were to be accessible to small and medium-sized enterprises that, unlike major companies, did not have the resources to undertake foresight work on their own. Foresight work was routinely undertaken by many major organizations. The technology foresight programme of the United Kingdom sought to build on both existing networks and specialized foresight studies that have already been established in many areas of industry. Fourteen sectoral panels were used to develop the technology foresight programme. Panel chairmen were drawn from industries and vice-chairmen from academia.

The panels first prepared preliminary surveys about perceived market and technology opportunities over the next 10 to 20 years in their respective sectors. Those surveys were prepared through consultation with a wider pool of experts as well as appropriate trade associations, R & D organizations, professional institutions, government departments and research councils.

The expected outputs of the programme were to be:

- A summary of the key findings of each panel
- Identification of situations where prospective market opportunities intersected with emerging technological opportunities
- An assessment of the priorities, the strengths and weaknesses of the United Kingdom industrial, science and engineering base
- Implications for wider government policy
- Early lessons to be learned for subsequent foresight work

Initially a steering group was appointed for the technology foresight programme. Awareness seminars were conducted and 15 sectors were chosen, including:

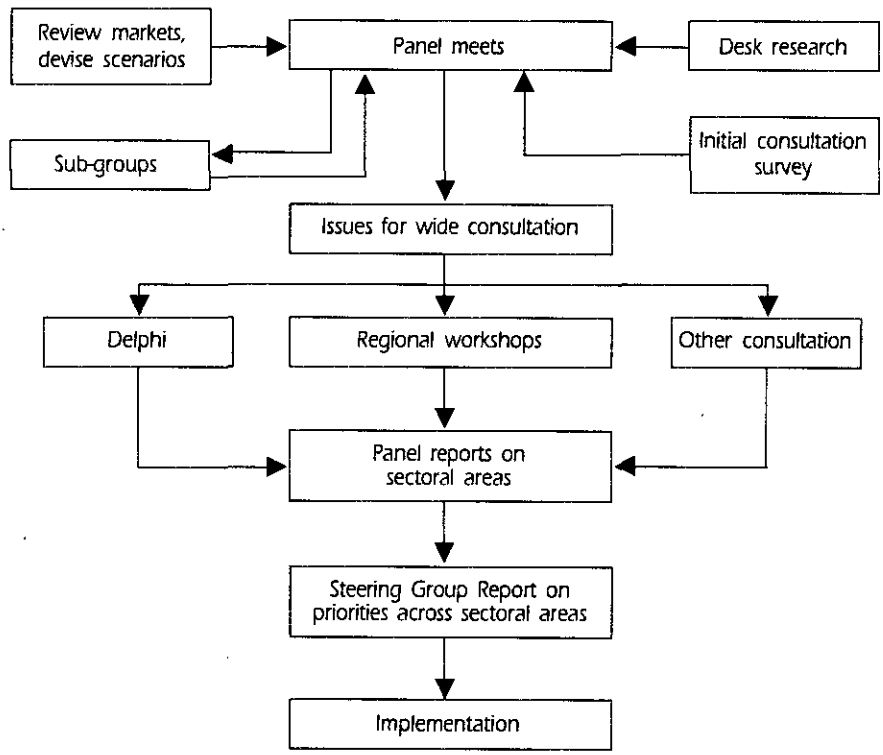
- ❑ Agriculture, natural resources and environment
- ❑ Chemicals
- ❑ Communications
- ❑ Construction
- ❑ Defence and aerospace
- ❑ Food and drink
- ❑ Health and life sciences
- ❑ Information technology and electronics
- ❑ Leisure and education
- ❑ Management of intersectoral links
- ❑ Manufacturing, production and business processes
- ❑ Materials
- ❑ Retail and distribution

The main foresight phase is given in figure 48 below. In this phase, the panel members constructed scenarios for their relevant areas of expertise, based on technology monitoring; then they identified key issues and prepared a technology-trend analysis and, finally, they consulted with the relevant communities.

The main phase was designed to obtain the necessary commitment and consensus needed to implement eventual findings. The panel identified six themes and 27 areas in terms of feasibility, attractiveness and relevance to the United Kingdom.

The subsequent phase of the scheme dealt with implementation. During this phase, various levels (government, industry and academic) were involved. They endeavoured to apply and exploit the results of the monitoring. An attempt was made to introduce a foresight culture in industry whereby firms, stimulated by participation in the programme, would be motivated to undertake targeted exercises in their specific sphere of activity. Foresight data was shared with firms that requested specific studies and relevant background information. This exercise became the basis for a policy initiative, effecting a cultural and structural change in the innovation system of the United Kingdom. The programme succeeded in mobilizing a large part of the expert community in the United Kingdom,

Figure 48. Main foresight phase: March 1994-March 1995



notably in industry where interaction was needed to gain a clear focus on future directions for innovation. A result has been that many firms have initiated their own foresight programmes.

Lessons learned

The lessons learned from the foresight programme in the United Kingdom have been presented by Martin and Irvine [9] in terms of five elements, namely:

- ❑ Communication: bringing people together in a novel forum where they can interact;
- ❑ Concentration: focusing on long-term trends in technology, where participants are encouraged to look further into the future than they would other-wise;
- ❑ Coordination: seeking alliances with different stakeholders in order to increase R & D productivity;
- ❑ Consensus: generating a clearer picture on the likely future scenario;

- Commitment: ensuring that individuals and firms participate fully and are able and willing to implement changes in the light of the foresight exercise;
- Comprehension: encouraging executives to understand the changes in their business at a global level and to exert some control over these events.

In order for information to be monitored and disseminated to a variety of users, there is a need for an institutional mechanism at the national level to be in place. A very useful approach has been the formation of interactive groups that involve various stakeholders.

EXPERIENCES AT THE REGIONAL LEVEL

Asia and the Pacific: APCTT

The Asian and Pacific Centre for Transfer of Technology (APCTT) is an organization under the jurisdiction of the United Nations Economic and Social Commission for Asia and the Pacific. The philosophical underpinning at the inception of APCTT was that networking and partnerships make it possible to reduce costs and improve the quality of technology transfer services of any agency involved in technology monitoring and transfer. APCTT is functioning as a well-networked technology transfer agency and is able to provide its clients with many alternative sources of technology. Decisions pertaining to the choice of technology are informed and appropriate owing to comprehensive technology monitoring. At present, APCTT handles more than 250 business-to-business introductions per annum, making it one of the most active technology transfer agencies currently operating in Asia and the Pacific region. The basis of APCTT's work is a strong monitoring network. The main focus of APCTT is monitoring innovative technologies that can be used commercially [10-11].

Methodology

The main focus of APCTT's work has been facilitating the transfer of technology. The starting point for this work was information collection and technological scanning. This was done through in-house expertise as well as through partners. Technology monitoring was a precompetitive function undertaken by APCTT. APCTT conducted its work through networking and partnerships. It has actively established partnerships and technology transfer networks since the early 1990s. (At present, APCTT has more than 1,000 partners in about 70 countries. Partners act as sources for information collection and dissemination of monitoring outputs.)

Instead of establishing a large single entity, APCTT worked through national technology information and transfer institutions. In India, APCTT cooperated with the Council of Scientific and Industrial Research and the National Small Industries Corporation in sourcing indigenous and foreign technology for industries, providing technological assistance as well as organizing technology transfer workshops. For disseminating the required information, APCTT undertook systematic monitoring of technologies available for transfer by scanning sources such as:

- National information networks
- Product catalogues and brochures of firms as well as technology consul-tants
- Trade journals and trade promotion magazines

Monitored information was disseminated in India, for example, through:

- Technology Information Promotion System Office (TIPS): information on opportunities in technology
- Consultancy Development Centre: information on international opportu-nities in technology
- National Research Development Corporation: marketing abroad the technologies developed in R & D institutions in India

In China, Sinotechmart was the major partner of APCTT in facilitating technology transfer and organizing training programmes, workshops and other events. APCTT also exchanged technological information through TIPS in China. APCTT, through its technology monitoring system, helped the China Science and Technology Exchange Centre in matching companies from China with prospective technology transfer partners from abroad.

In the Republic of Korea, APCTT cooperated with the Korea Institute of Industrial and Technology Information (KINITI), in the field of information exchange and dissemination. APCTT disseminated the technology monitoring information for small and medium-sized enterprises through this partnership.

In Malaysia, Pakistan, the Philippines and Thailand similar arrangements were used by APCTT for collecting, monitoring and disseminating information.

Medium for exchange of technological information

The collection of information by APCTT was done through the Mechanism for Exchange of Technology Information (METI). METI was a UNDP-funded project aimed at the establishment of a regional network for collection and dissemination on environmentally-sound technologies available for transfer to small and medium-sized enterprises in Asia and the Pacific region. Eleven countries, namely, Bangladesh, China, India, Indonesia, Malaysia, Nepal, Pakistan, the Philippines, Republic of Korea, Thailand and Viet Nam were members from 1991 to 1993. In the period from 1994 to 1996, Cambodia, Lao People's Democratic Republic, the Russian Federation and Sri Lanka joined the project. METI was coordinated by APCTT, while all activities at the national level were prepared by APCTT, in cooperation with METI national nodal agencies designated by the countries.

International Network for Transfer of Environmentally Sound Technologies

International Network for Transfer of Environmentally Sound Technologies (INTE) was formed in 1994. The network targeted small and medium-sized enterprises and technology consultants. It was a rapidly growing network that helped small and medium-sized enterprises to grow and compete in local and international markets. APCTT provided the INTET members with an integrated bundle of services that included:

- Information on technology, business and investment opportunities
- Worldwide search for business and technology partners
- Consultancy for subcontracting
- Marketing assistance

Information on environmentally sustainable technologies and cleaner production was provided by APCTT to INTET members on a regular basis. This made it possible to realize the principle of continuous technology monitoring for small and medium-sized enterprises in a cost-effective manner. A large number of technologies were shared across a variety of users spread over various countries and included:

- Clean production technologies
- Ecofriendly product development
- Environmental management
- Waste recycling
- Waste reduction

To make the networking and consulting process as comprehensive as possible, APCTT had also been developing linkages with various financing institutions that provided venture capital grants or low-interest loans for environmental projects.

Networking with consultants

In its efforts to extend its services to a large group of small and medium-sized enterprises, APCTT closely cooperated with technology transfer brokers and management consultants worldwide. This network was made self-sustaining through mechanisms such as:

- Sharing of technology transfer fees
- Memberships
- Sale of information

APCTT initiated partnerships with technology transfer institutions from outside the region such as:

- Technology Exchange Ltd (United Kingdom)
- Lomar Associates (Canada)
- ARIST (France)
- FORBAIRT (Ireland)
- RKW (Germany)
- Russian House (the Russian Federation)
- Centro Estero Camare Commercio Piemontesi (Italy)
- Intermatch Corp (United States)
- IL & FS (India)
- Delphi (Canada)

Monitoring, with active involvement of organizations from developed countries, increased the developed country/developing country technology exchange. The networking between developed and developing countries and, equally, between developing countries with each other, made APCTT monitoring a broadly based cost-effective system.

Asia Pacific Tech Monitor

APCTT published a bimonthly journal, *Asia Pacific Tech Monitor*, which provided monitoring results in a number of formats for wider dissemination, namely:

- Trends in technological transfer

- Trends in technological development: technological advances in selected areas
- Technology availability: information on technologies available to users
- Requests for technology: names of organizations interested in purchasing technology
- Technology policies
- New products available for commercialization
- New services

The programme was a major success and helped many industries. APCTT monitored information and facilitated technology transfer. For these reasons, the service was cost-effective and financially self-supporting.

Value-added technological information service

APCTT produced a quarterly bulletin that provided value-added technology monitoring information in the form of business opportunities in new technologies. The issues covered were:

- Waste technology
- Biotechnology
- Food processing
- Renewable energy

Each issue covered the latest technology ideas. This was tailored to the needs of policy makers, industries and technology transfer intermediates.

Japan-India technology network

This network was a platform for Japanese and Indian businessmen to exchange information and to promote Indo-Japanese technology cooperation. It facilitated sharing of information on science, technology and business, with specific emphasis on the transfer of technology to small and medium-scale enterprises. The network also provided an opportunity for Indian research institutions to market technology in Japan and for business to learn from Japanese experience.

The network covered:

- A technology transfer database
- Corporate, business and information
- Governmental information

This was an effective way of monitoring technology, especially for small and medium-sized enterprises.

Lessons learned

The APCTT experience shows that a regional network can be very cost-effective for technology monitoring. Combining monitoring and transfer activities has been very effective in networking various agents involved in the innovation chain. Instead of monitoring all major technologies, it has concentrated its efforts on selected areas that fall within the category of small and medium-sized enterprises, in particular, on selected areas such as chemicals, waste reduction, agroprocessing and construction technology. The model used by APCTT has been found to be effective in bringing together partners for interactions between developing countries as well as interactions between developed and developing countries. A similar model may lend itself to replication in other parts of the globe. Regular publication of the results of monitoring has been shown to be very beneficial.

Latin America

Governments, national institutions, international organizations as well as national and transnational enterprises promote research about the future so as to evaluate the impact of new developments [12]. The Latin American Economic System (SELA), recognizing the importance of technology forecasting, started an institutional arrangement for promoting monitoring and long-term thinking.

SELA is a regional organization that encompasses 27 sovereign Latin American and Caribbean countries, for the purpose of coordinating joint positions and promoting coöperation among its members.

One of the major activities of SELA has been an "analysis of long-term scenarios". In compliance with the provisions of SELA, a meeting entitled Experts for the Analysis of Long-Term Scenarios was organized. The Latin American Commission on Science and Technology (COLCYT) of SELA presented the COLCYT Model for Competitive Management. According to the model, technology is a strategic input for competitiveness. This must be acknowledged, fully understood and managed in such a way that it is granted priority in:

- Devising industrial policies
- Implementing cooperation programmes
- Planning economic integration and an approach to globalization

The approach of SELA has been to use instruments such as strategic planning, forecasting, monitoring, techno-economic intelligence, quality management and technology management so as to generate an integrated conceptual and operative framework aimed at strengthening competitiveness. The output will be used for:

- ❑ Modernization of industries
- ❑ Technology upgrading and retrofitting
- ❑ Industrial restructuring

In order to understand the role played by each of the business functions, as well as their close interdependence, a model was used, shown *in figure* 49 below.

Strategic planning represents the formulation of plans, strategies and specific actions directed at ensuring the enterprise's sustainability in the market. Technology forecasting represents formulation, evaluation and analysis of possible and probable future scenarios in the technical, commercial and social areas in which the enterprise will be operating. Technology forecasting permits the identification of emerging technologies. This creates a focus for the company's efforts in creating and generating new expertise in the company. One of the crucial elements of the model is the fundamental link that ties technology forecasting and management to the technology information system. These two disciplines are fundamental to policy analysis and decision-making.

The main support activity for forecasting has been the Latin American Information Network on Technology (RITLA). This is an intergovernmental, international public law organization, constituted under the guidance of the Latin American Economic System. The objective of RITLA is to promote regional scientific and technological cooperation with a view to achieving the integration of Latin America by disseminating expertise and

Figure 49. COLCYT model for competitive management

	Productive and commercial management	Management of information received	Management of know-how
Long-term management	Strategic planning	*Commercial and* technology monitoring	Commercial and technology *forecasting*
Short-term and medium-term management	Quality management		Technology management

information. The member States of RITLA are Argentina, Brazil, Mexico, Nicaragua and Venezuela. The main clients of RITLA include information networks and country hubs, teaching and research centres, private and public entities of the member States of RITLA.

The technology monitoring services provided are as follows:

- Information support to projects oriented to regional integration and with a common interest in science and technology;
- Technical and policy coordination for the integration of information technology networks and for promoting cooperation among R & D institutes in Latin American countries;
- Support of projects that provide macro studies on technology development in Latin America, business development, new technologies and the basic telecommunication infrastructure;
- Information exchange and mediation in presentations to international science and technology financing institutions on projects of interest to RITLA.

The following were provided:

- Studies on information networks and systems existing in Latin American countries
- A survey of the main technical, scientific and technological cooperation entities operating in Latin America
- A survey of the main Latin American political and economic cooperation entities
- A survey of the main entities providing financing and support of development in Latin America

Lessons learned

The regional experience of SELA shows that there are enormous advantages in having a regional network. The cost of information collection is pooled and shared. The second major lesson to be learned from the SELA experience is that creating awareness can be more effective at a regional level. It is also possible to bring together a variety of experiences on monitoring and collective action at a global regional level.

References

1. R. A. Slaughter, "Foresight Beyond Strategy", *Long Range Planning*, vol. 29, No. 2, 1996, pp. 156-163.
2. R.A. Slaughter, "Assessing the Quest for Future Knowledge: Significance of the Quick Environmental Scanning Technique for Futures", *Futures*, vol. 22, No. 2, 1990, pp. 153-166.
3. B. Bowonder and T. Miyake, "Technology Forecasting in Japan", *Futures*, vol. 25, 1993, pp. 757-777.
4. Exploratory Research for Advanced Technology (ERATO): 1995, Research Development Corporation of Japan, Tokyo, 1995.
5. Ministry of Economic Affairs, "Technology Foresight Studies", Government of the Netherlands, The Hague, 1994.
6. B. Van Vliet, "Country Study: South Africa", Meeting on Cooperation in Technology Monitoring in Developing Countries, UNIDO, 22-25 November 1994, New Delhi.
7. B. Van Vliet and A. Botha, "Technology Monitoring in South Africa", presentation to Meeting on Cooperation in Technology Monitoring in Developing Countries, UNIDO, 22-25 November 1994, New Delhi.
8. L. Georghiou, "The UK Technology Foresight Experience", *Futures*, vol. 28, No. 4, 1996, pp. 359-377.
9. B. Martin and J. Irvine, *Research Foresight*, Pinter, London, 1989.
10. Asian and Pacific Centre for Transfer of Technology: *1995 Annual Report*, APCTT, New Delhi, 1995.
11. Asian and Pacific Centre for Transfer of Technology: *Technology Promotion*, APCTT, New Delhi, 1995.
12. A. Leone, "Experiences of SELA", Meeting on Cooperation in Technology Monitoring in Developing Countries, UNIDO, 22-25 November 1994, New Delhi.

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