Application of

Technology Foresight

APEC Industrial Science and Technology Working Group

Ministry of Science, Technology and Environment, Thailand

Ministry of Foreign Affairs, Thailand

Thailand's National Science and Technology Development Agency

ISBN 974-7577-87-9

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Proceedings of the Public Seminar on the Occasion of the Launch of APEC Center for Technology Foresight
Bangkok, Thailand
August 1998

ISBN 974-7577-87-9

http://www.nstda.or.th/cyberbookstore
Printed by the Publications Department
National Science and Technology Development Agency, Bangkok, Thailand.
August 1998

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Foreword

The APEC Center for Technology Foresight was established following over two years of effort, and with the cooperation of people, organizations and institutions inside and outside Thailand. It was officially launched on 3rd February 1998, with an opening ceremony and one-day public seminar, followed by a three-day training workshop. These launching events were organized by the APEC Industrial Science and Technology Working Group, (APEC ISTWG), the Thai Ministries of Science, Technology and Environment, and of Foreign Affairs, and the National Science and Technology Development Agency of Thailand.

The launching activities gained the attention and interest of people from inside and outside Thailand. Over 150 people attended the opening ceremony and public seminar, while 30 participants joined the workshop. The opening ceremony was presided over by H.E. Mr. Yingpan Manasikarn, Minister of Science, Technology and Environment of Thailand. Honorable guests included representatives from the Bangkok embassies of 7 APEC members, delegates from 9 APEC member economies, and many distinguished Thai guests. Opening remarks were also provided by a representative of the APEC Secretariat.

The public seminar offered an introduction to technology foresight and its application. This book contains the papers presented at this seminar, in order to disseminate this knowledge more widely. The interactive workshop provided the attendees with “hands-on” training in using technology foresight techniques, focusing especially on the methodologies of Delphi and Scenario-building. The book also contains a summary report of this event, along with all the Addresses at the opening ceremony, and further information about the APEC Center for Technology foresight personnel.

Located in Bangkok, the APEC Center for Technology Foresight is an independent unit of NSTDA. Its runs its own activities and operations under the guidance and supervision of two boards: the Steering Committee and the International Advisory Board. With a small core staff, the Center operates as a virtual Center, exploiting modern communications infrastructure to network with the rest of APEC and elsewhere in the world. During its establishment and initial activities, the Center has used the resources and facilities available at NSTDA. Apart from this generous and on-going support of the Royal Thai Government, the Center seeks, and will depend upon, additional resources and contributions from outside Thailand.

Technology Foresight has been used as an effective tool for strategic planning of science and technology development in some advanced countries for decades. Industrializing countries have also recently adopted the methods of foresight studies to prioritize research and development in their countries. The newly established APEC Center for Technology Foresight attempts to promote the adoption of technology foresight, and develop technology foresight capabilities, throughout the APEC region, as well as to facilitate and motivate multi-economy technology foresight studies. The Center exists to serve all APEC economies and encourages all the members to get involved in its activities.

The establishment of the APEC Center for Technology Foresight is the culmination of the efforts of people from many countries working together to realize a shared dream. It illustrates the potential benefits of international cooperation and suggests a way forward for the international resolution of critical problems, and for shaping the future together. The future success of the Center will depend upon the continued commitment towards international cooperation, of individuals and institutions inside and outside Thailand.

Professor Yongyuth Yuthavong

Acting Director of NSTDA
February 1998

Technology Foresight : Philosophy & Principles

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1. Introduction

Science and technology are vital to our society, economy and environment. They lead to wealth creation and improvement of the quality of life. Successful exploitation of technology has become critical to achieving economic competitiveness. However, we live in a world which is changing rapidly and where global environmental issues, such as climate change resulting from increasing emissions of greenhouse gasses or pollution of the oceans, are emerging as threats to our progress. To cope with these changes, our science and technology systems must be able to respond and change, either by adapting existing technologies or developing and applying new ones. The value of Foresight is that it provides a structured opportunity to look ahead and consider the role that may be required of science and technology in the future.

2. Definition and Rationale

Various definitions of 'Foresight' have been proposed, but the one that provides the best description is: "Foresight involves systematic attempts to look into the longer-term future of science, technology, the economy, the environment and society with a view to identifying the emerging generic technologies and the underpinning areas of strategic research likely to yield the greatest economic and social benefits."

There are a number of implications of this definition :

a) the attempts to look into the future must be systematic to come under the heading of 'Foresight';
b) these attempts must be concerned with the longer-term, typically 10 years and possibly 5-30 years;
c) 'Foresight' is a process rather than a set of techniques and involves consultation and interaction between the scientific community, research users and policymakers;
d) one focus is on the prompt identification of emerging generic technologies, i.e. technologies whose exploitation will yield benefits for several sectors of the economy or society. Such technologies are still at a pre-competitive stage and can be targeted for selective funding to ensure rapid development;
e) another focus is on strategic research, i.e. basic research carried out with the expectation that it will produce a broad base of knowledge likely to form the background to the solution of recognized current or future practical problems;
f) attention must be given to the likely social benefits (and disbenefits) of new technologies and not just their impact on industry and the economy.

It is important to stress that Foresight is not the same as technology forecasting which assumes that there is an unique future. It is then the task of the forecaster to predict, as accurately as possible, what this will be.

By contrast, Foresight is concerned not so much to predict the details and timing of specific developments as to outline the range of possible futures which emerge from alternative sets of assumptions about emerging trends and opportunities. Exactly which one is arrived at depends upon the choices made in the present. Foresight offers the chance to shape the future though wise decision making.

3. Outputs of Foresight

A critical feature in setting up a 'Foresight process' is to define the aim since this determines the nature of the linkage with the decision-making process. Six possible aims are:

1. direction setting - broad guidelines in science policy and the development of an agenda of options;
2. determining priorities - perhaps the most important aim of Foresight and the driving force in most of the documented country exercises against a background of resources restraint and increasing demands from researchers;
3. anticipatory intelligence - identification of emerging trends with major implications for future policy making;
4. consensus generation - promotion of greater agreement among scientists, funding agencies and research users on identified needs or opportunities;
5. advocacy - promotion of policy decisions in line with preferences of specific stakeholders in the R&D system;
6. communication and education - promotion of internal communication within the scientific community, promotion of external communications with users of research and wider education of the general public, politicians and bureaucrats.

There are thus a number of activities that can be gathered up loosely under the term Foresight, some relatively old, others quite recent in origin. The methods used to conduct foresight exercises have been subjected to critical scrutiny in the 1990s and there is a widespread view that the economic, institutional and cultural context of different countries should influence the choice between approaches. For example, Australia which is a small to medium sized economy with a strong public sector presence in basic science, a correspondingly weak though growing private sector presence in R&D, and a commodities-influenced economy, needs to contemplate a different kind of future than would be the case in a major economy like Japan with a strong industrial base, limited natural resources and developed high technology.

The essential ingredients of Foresight are shown in Figure 1. In conducting a 'Foresight Study' it is necessary to maintain a balanced perspective between the 'science-push' and 'demand-pull' factors that influence future developments.

- Science-push factors include the creation of new technological or commercial opportunities by scientific research, and the strength and resources to exploit them.
- Developments in technology and production can create a use for existing and novel science through the mechanism of demand-pull. Demand factors include the priorities and needs of the broader community.

There can be problems in communication between proponents of science-push and demand-pull, particularly their different time perspectives. The time horizon of those making the demands may be too short for an effective dialogue. Looking ahead together, through Foresight, can bridge this gap in many cases.

Because of the interactive nature of Foresight the outputs of the process can often be as important (or even more important !) as the products. We can list the process benefits as the six Cs' :

- **communication** - bringing together disparate groups of people together and providing a structure within which they can interact and communicate;
- **concentration** - on the longer term, so participants look further into the future than they otherwise might:
- **coordination** - enabling different groups to form productive R&D partnerships;
- **consensus** - so a clear picture of alternative future directions and research priorities can be formed;
- **commitment** - generating a sense of commitment to the results among those who will be responsible for implementing changes in light of the foresight exercise; and
- **comprehension** - to encourage those involved to understand the changes happening in their business, or professions, at a global level, and to exert some control over these events.

The success or otherwise of a foresight exercise can be gauged by assessing it against these six criteria.

Finally, experience has shown that Foresight needs to be carried out at several levels, ranging from bodies responsible for the coordination of overall national science and technology policy, through industrial associations down to individual companies or research organizations. Thus, some Foresight exercises need to be more macro level, or "holistic", in scope whilst others need to be focused at a more micro-level. Furthermore, the Foresight activities at different levels should be fully integrated, the results from higher and / or lower levels of Foresight being fed into the process, and the results in turn feeding into subsequent Foresight efforts at higher or lower levels.

4. Priority Setting

Increasingly the driving force of Foresight exercises has been the setting of priorities at all levels. To set priorities is to make a conscious choice between activities, preferring the more important to the less important. The stimulus to do so is usually a pressing shortage of time, of money or of energy. The implementation of early Foresight exercises foundered on the opposition from entrenched groups, both in academia and in industry, who saw priority-setting as a threat. However there is now a recognition by the bureaucratic, industrial and scientific communities that difficult decisions do indeed have to be made on national research priorities and that strategic planning and priority-setting are unavoidable. The environment in which the latest exercises have been conducted is a vastly different one to that of the early to mid 80s. Priority setting can result from decisions taken at several levels - from the 'top-down' approach at the political / policy level, through the strategic or middle level to the 'bottom-up' approach of the operational level. Thus, as noted earlier, Foresight needs to be carried out at several levels, ideally in an integrated fashion.

Experience has shown that the essential features for a successful Foresight exercise directed to priority setting are :

- the aim of the Foresight activity needs to be explicitly defined at the beginning;
- research users, producers and funders are all involved;
- at least as much attention is paid to the 'top-down' as to the 'bottom-up' flow of advice;
- the implementation mechanism needs to be in place so that decisions made in the process can, and will be, implemented;
- the process is sensitive to the unexpected, so that plans can be modified;
- the process is not 'one-off', but is repeated at regular intervals to take account of feedbacks and new developments.

For national priority setting to succeed, it is essential that clear support is given by the highest levels of Government, that the scientific and technical community accepts the Foresight process and its outcomes, and that industry is closely involved and also accepts the Foresight process and its outcomes.

5. Foresight Methodologies

As noted earlier, there are a number of activities that can be gathered up under the term Foresight and not surprisingly a number of methodologies have been developed. Several are described here and their application will be discussed by the later speakers.

1. Extrapolation - this is essentially a short-term approach which assumes that the future is an extension of the present and that the economy, society and technology will continue in a steady pattern. The recent financial crisis in Asia indicates the deficiencies of this approach!

2. Delphi Surveys - This uses experts to identify possible technological developments in say 10-20 years and to estimate the likelihood of their occurrence and realization time. The method involves sending a questionnaire to a large panel of experts repeatedly to encourage group interaction. The panel members usually have widely varying estimates in each question at the beginning of the process and convergence occurs as the process proceeds. However it is important to recognize that the outliers may sometimes have a better view of the future than the majority!

The Delphi technique has a number of advantages. Firstly, it permits a synthesis of the views of large numbers of experts. Secondly, it is suitable for looking at the longer- term, e.g. 10 to 30 years into the future. Thirdly, it is good at generating the process benefits (of consensus and concentration) described earlier. Lastly, it can be applied in different countries, thus allowing the researcher to compare the results to identify the effect of any national influences. Among the disadvantages are the fact that large-scale Delphi surveys can be expensive and time-consuming, and they need the participation of a large number of experts if the results are to be statistically significant.

The Delphi technique has been extensively used in Asian countries, notably Japan, Korea and Thailand, and also in Europe mostly Germany and France.

3. Consultation - This uses a broad ranging approach across the community to develop perspectives on expected, possible and preferred futures on a longer-term basis (10-20 years). Expected futures are based on the analyses of experts and current trends and extrapolation. Possible futures provide a range of options for a world that might change significantly over time. Preferred futures are those that a community wants to achieve; they encompass individual values and aspirations, the strategies of corporations and community organizations and the plans of governments. By comparing these, it is possible to identify key issues and key forces for change that need to be addressed in developing a national strategy to reach the preferred future while coping with possible changes.

This technique is good at generating the process benefits of communication, coordination, commitment and comprehension described earlier. Like Delphi, the process can be expensive and time-consuming since large numbers of people are involved in consultations. Unlike Delphi, it tends to be country and culture specific and results cannot be compared readily.

The consultation technique has been used in Australia and the Netherlands. A recent exercise in the U. K. involved consultation as well as Delphi.

4. Scenario Writing - This uses a more focused approach than (3) to develop scenarios for the future and assess their implications. Small groups of experts and stakeholders identify likely developments in technology in a particular field over, say the next 10-20 years. They then speculate on possible, even improbable, events, which could occur to change the pattern of development, e.g. major political changes, wars, natural events such as earthquakes and create scenarios to take account of best & worst cases. These provide a basis for strategy development to allow a flexible response to dramatic change.

The scenario writing technique has been used by corporations and by research organizations to develop business strategies and to aid in priority setting. The technique is good at generating the process benefits of the 6 Cs described earlier.

5. Patent Analysis - This is a short-term approach which uses patent databases to identify emerging technologies and their possible applications in other fields. It is a well-known technique used for corporate innovation planning and competitor analysis, but care is needed when using patent data for Foresight analysis. Most national data are biased towards the country of origin and cannot be used for true international comparisons.

The main advantage is that analysis can be performed with on-line databases on a regular scale, e.g. annually with moderate costs and labor investment. It has been used in Germany by high technology companies.

6. Critical Technologies - This technique uses a small selected group of experts on a one-off basis to develop a list of generic technologies relevant to the future economic development of a country. It has been used to define critical technologies for industry and for defence in the U.S.

The main advantage is that it is relatively easy to carry out the exercise. The disadvantages are that it achieves little of the process benefits of Foresight, and the results are biased by the opinions of the group and tend to be too general to be useful for detailed strategy or priority development.

6. Concluding Remarks

Foresight is now accepted in many countries as a means of focusing the efforts of the scientific and technological community (in the broadest sense) towards wealth creation and improvement of the quality of life. The primary rationale is the widespread recognition that emerging generic technologies are likely to have a revolutionary effect on industries, the economy, society and the environment over coming decades. These technologies are heavily dependent for their development on advances in science. If one can identify emerging technologies at an early stage, governments and others can target resources on the strategic research areas needed to ensure rapid and effective development.

While there are various methodologies for carrying out the Foresight process, it is clear from experience that the economic, international and cultural contexts of different countries must influence the choice of the methodology used and that combinations of methodologies can be extremely effective. The challenge in the APEC context, where there are 21 economies in a wide range of economic, social and technological development, is to stimulate the use of appropriate Foresight techniques on a national basis and to apply (and if necessary develop) Foresight methodologies on a regional basis for mutual benefit.

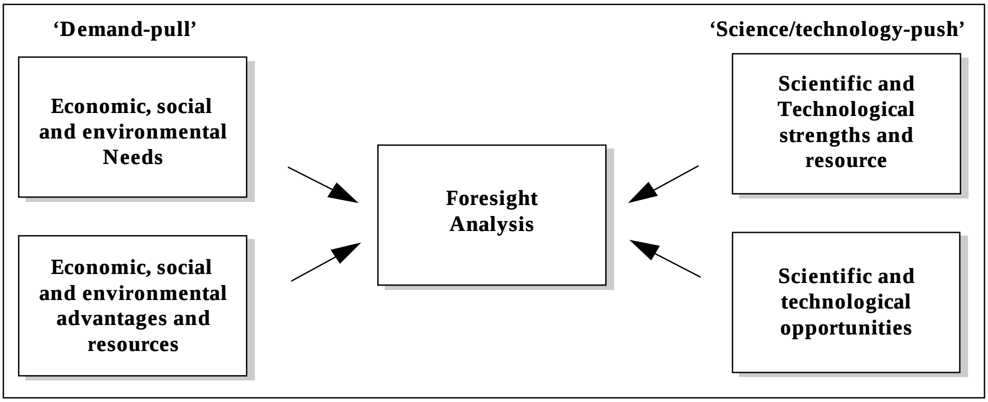

Fig. 1 Factors Influencing Foresight.

An Outline of the Sixth Technology Forecast Survey

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Section 1: Outline of the Survey

1. Objectives

The National Institute of Science and Technology Policy (NISTEP) has to date conducted technology forecast surveys, generally every five years, since 1971 to ascertain the future direction of technology in Japan from a long-term viewpoint. This is the sixth survey conducted.

The promotion of science and technology is pivotal to the sound growth of Japanís business community, so it is crucial that we fully grasp the future direction of technological development from a long-term viewpoint.

In this light, we conducted a technology forecast survey that took in the next 30 years to ascertain the future of technology in Japan, and through this, contribute to the formulation of science and technology policy, and provide a basic reference point for technology strategies in the private sector.

2. Implementation structure

For the survey, NISTEP established a technology forecast committee to examine the overall survey plan and implementation guidelines, and IFTECH established 13 subcommittees* headed by members of the technology forecast committee to set the survey topics in each field, select the survey participants, and analyze the survey results. NISTEP conducted an analysis of all fields handled by

* Of the 14 fields covered, “ Resources and energy” and “Environment” are closely related, and were handled by a single subcommittee.

the survey, and the technology forecast committee prepared a comprehensive report based on these analysis results.

3. Outline

1.1 Survey fields

The survey covered the following 14 fields.

- Materials and processing
- Electronics
- Information
- Life science
- Space
- Marine science and earth science
- Resources and energy
- Environment
- Agriculture, forestry and fisheries
- Production and machinery
- Urbanization and construction
- Communication
- Transportation
- Health, medical care and welfare

The fifth survey contained 16 fields, but the following changes were made for this survey.

- “Information and electronics” was divided into “Information” and “Electronics”.
- “Mineral and water resources” and “Energy” were combined into “Resources and Energy”.
- “Particles” and “Lifestyle and culture” were removed as independent fields and incorporated into other fields.
- “Production” and “Health and medical care” were changed to, respectively, “Production and machinery” and “Health, medical care and welfare”.

1.2 Forecast period

The forecast period is 30 years from 1996 (the year the survey was conducted) to 2025.

1.3 Survey method

Like the previous survey, this survey was conducted using the Delphi method, and responses were consolidated through two questionnaires.

Delphi method: The Delphi method is a method of consolidating respondents’ views by repeatedly giving the same questionnaire to a large number of people. In the second and subsequent questionnaires respondents receive a feedback of the results of the previous questionnaire so that they can reassess their answers to the questions in the light of the overall trend of views. This is the major characteristic that sets the Delphi method apart from ordinary survey methods. Respondents who are not confident in their answers will generally tend to support the majority view, so it is possible to consolidate their views. The Delphi method, developed by the U.S. Rand Corporation, was named after the site of the oracle of Apollo in ancient Greek mythology, and according to legend, many gods used to gather there to foretell future events.

1.4 Setting the topics

The topics were set by the various subcommittees. The process began with the subcommittees determining the scope of the survey in each of the field, categorizing the future direction of technological development, and preparing a framework that would ensure important topics were not omitted. They then drew up a list of topics. This was done within the following parameters set by the technology forecast committee.

- Review the topic framework of the 5th survey in view of recent technological trends.
- The number of topics should generally be the same as the previous survey, with identical topics, revised topics and new topics each accounting for roughly $^1/_3$ of the topics.
- Set the forecast topics with consideration given to an intersection of technological fields (four axes of aging countermeasures, safety, environmental preservation and recycling, and common base technologies, whose integration with technologies in a large number of fields is considered necessary when looking at future technological trends).
- In principle, topics that have no technological elements and are connected only to socioeconomic conditions should not be included in the survey.
- In principle, survey topics should be those thought to be realizable by 2025. Where necessary though, topics that are realizable after 2025 may also be included.
- In principle, the technological stage of each topic should be expressed by one of the four keywords of “elucidation”, “development”, “practical use” and “widespread use”.
- As for the place of realization, unless specifically mentioned the topic should assume realization anywhere in the world, that is the country or region where realization is earliest.
- Two or more forecast particulars should not be included in one topic.
- Topics should include specific objective values and champion data wherever possible, and should present an image of specific use and application.
- Where necessary, identical forecast topics should be surveyed in more than one survey field.

After the subcommittees evaluated previous topics, examined new topics and prioritized topics according to importance, they finally settled on 1,072 topics for the survey.

1.5 Selecting survey respondents

For the most part, members in each of the subcommittees were asked to recommend experts in their respective fields as potential respondents. Our intention was to obtain as large a list as possible of experts with extensive knowledge in the relevant topics or technological fields, keeping in mind the need for a good cross-section of representatives from industry, the government and academia. In some cases however, rather than recommendations of individual names, the Secretariat chose respondents at random from a list put forward by the subcommittees.

The main people we were looking for as respondents were “people in research and development, research managers and others in corresponding positions who have expert knowledge in the relevant survey fields”. We also considered people with the following attributes.

Sector (occupation)

The overall percentage breakdown of respondents across all fields in the fifth survey was company-related 37%, university-related 36%, public research institutions 15%, and others 12%, and for the sixth survey we aimed at a similar industry-academia-government mix.

Age composition

For this survey we tried to increase the number of relatively younger respondents in their 30s and 40s (in the previous survey, most respondents were in their 50s, followed by those in their 40s, then 60s). We also tried to increase the proportion of female respondents (only 1% in the previous survey).

We asked potential respondents identified through the above process whether they would be prepared to cooperate in the survey, then chose those who were prepared to cooperate to take part in the first questionnaire. For the first part of the survey we sent questionnaires to 4,868 respondents, of whom 4,196 were sent questionnaires for the second part. We excluded those who decided to withdraw from the survey after the first questionnaire.

The breakdown of final respondents by sector for this survey is generally the same as it was for the fifth survey. By age, the number of respondents in their 30s and 40s increased over the previous survey, though only slightly. An increase was also recorded in female respondents, but here too, the increase was quite small (see Tables 3-1 and 3-2).

1.6 Survey items

We drew up the questionnaires in question form covering the survey items listed below for each of the topics set at (4) above (for details see 4. Reading the survey results)

Degree of expertise

Degree of importance to Japan

Expected effect

Forecasted realization time

Current leading countries etc.

Effective measures the government should adopt in Japan

Potential problems in Japan

1.7 Implementation of the questionnaires

The questionnaires were sent to respondents as follows.

First questionnaire: August 1996

Second questionnaire: December 1996

For the survey we asked the respondents to give their responses assuming that over the next 30 years there would be no wars of a global scale or natural calamities to cause socioeconomic upheaval. In the second questionnaire we included the results of the first questionnaire for reference by the respondents.

The second questionnaire questioned respondents on the same topics as the first, though the wording of some topics was reviewed and revised in the light of comments by the respondents in the first questionnaire.

1.8 Response assumptions

- In principle, this technology forecast covers what are considered to be key R&D topics over the roughly **30-year period from 1996 to 2025**.
- There will be no wars of a global scale or natural calamities that would cause socioeconomic upheaval over the next 30 years.
- Unless expressly indicated in the topics with such terms as “in Japan”, topic realization means **realization anywhere in the world**.

4. Reading the survey results

Topics

In some cases the two questionnaires differed slightly in the wording of the topic, but here we have used the wording contained in the second questionnaire. The definitions of the keywords used in the topics are as follows.

Elucidation	:	To scientifically and logically identify principles or phenomena.
Development	:	To attain a specific goal in the technological aspect (e.g. completion of a No.1. prototype).
Practical use	:	To be practically used after being proved economically viable (e.g. completion of the first object that can be actually presented for practical use).
Widespread use	:	To be widely and commonly used after an object is put to practical use.

Number of respondents

The number of respondents of the questionnaire shows the total number of respondents indicating a “high,” “medium” or “low” degree of expertise (the number who indicated “none” is not shown).

Degree of expertise

The degree of expertise shows a percentage breakdown of respondents in above who indicated a “high,” “medium” or “low” degree of expertise. Respondents were asked to select one of the expertise degrees defined below.

High	:	Has considerable specialist knowledge about the topic through current research or work related to the topic (including research based on literature).
Medium	:	Was once engaged in research or work related to the topic; or has some specialist knowledge about the topic through research or work in an adjoining field.
Low	:	Has read technical books or literature about the topic or has listened to experts connected with the topic.
None	:	Has no expertise.

Degree of importance to Japan

The degree of importance to Japan shows a percentage breakdown of respondents who indicated "high," "medium," "low" or "unnecessary" for the topic's importance. The index was worked out from the following equation; the index is 100 when all respondents indicate "high" and 0 when all indicate "unnecessary".

Degree of importance index = (number of "high" responses x 100 + number of "medium" responses x 50 + number of "low" responses x 25 + number of "unnecessary" responses x 0) ÷ total number of degree of importance responses.

Respondents were asked to select one of the importance degrees defined below.

High	:	Extremely important
Medium	:	Important
Low	:	Somewhat important
Unnecessary	:	Not important

Expected effect

The figures here show the percentage of the respondents who selected each of the four expected effects of the topic's realization, listed below. For this, respondents were allowed to select more than one effect (or none if nothing was applicable).

Contribution to socioeconomic development	:	Development of innovative products, creation of new industries, expansion of economic frontiers, development of the socioeconomic base, etc.
Resolution of various problems of a global scale	:	Global environment, food, energy, resources, etc.
Response to people's needs	:	Prevention and cure of disease, improvement of the living environment, support for elderly people and people with disabilities, disaster prevention and safety, etc.
Expansion of human intellectual resources	:	Discovery of new laws and principles, construction of original theories, etc.

Current leading countries etc.

This shows the percentage of respondents at who selected each of the six countries or regions below as a world leader in the topic in question. Respondents were allowed to select more than one country or region.

- USA
- EU
- Former Soviet Union and Eastern European countries
- Japan
- Other countries (enter specific country in the response column)
- Do not know

(As of May 1996 the EU comprises the 15 countries of Germany, UK, France, Spain, Netherlands, Greece, Belgium, Portugal, Sweden, Austria, Denmark, Finland, Ireland and Luxembourg.)

Effective measures the government should adopt in Japan

This shows the percentage of respondents at who selected each of the seven items below as effective measures that the government should adopt in Japan to promote R&D aimed at the realization of the topic in question. Respondents were allowed to select up to three separate measures. No selection was made where it was believed no measures were appropriate considering the nature of the topic; for example, realization was best left up to market forces.

- Foster researchers, engineers and research assistants
- Enhance systems to promote personnel exchanges among the industrial, academic and government sectors and cooperation among different fields of science and technology
- Upgrade advanced R&D facilities and equipment and make them available for more widespread use (covers facilities and equipment at national research institutions, universities and other public research institutions)
- Develop a research base comprising data bases, standard reference material, genetic resources and the like
- Increase the government's funding for research (including research subsidies for private companies etc.)
- Adjust relevant regulations (relax / toughen / establish / abolish; including such tax measures as promoting the widespread use of electric cars by introducing a carbon tax)
- Others (enter specific measures in the response column)

Potential problems in Japan

This shows the percentage of respondents at who selected each of the four items below as potential problems that realization of the topic in question could create in Japan. Respondents were allowed to select up to two items (none if nothing was applicable).

Adverse effect on the natural environment	:	Increased destruction of the natural environment, including air and water pollution, destruction of ecosystems, etc.
Adverse effect on safety	:	Adverse effect on disaster prevention, health, security, privacy etc. (occurrence of natural disasters, increase of crime, improper use of personal information etc.).
Adverse effect on morals, culture or society	:	Adverse effect on life ethics, human psychology, traditional culture, human relations, regional communities etc.
Other adverse effects	:	(enter specific effects in the response column)

Section 2: Outline of the Results

1. Topics with a high degree of importance

1.1 Overall trends

Here we shall look at forecasts for those of the 1,072 topics in all fields (referred to as all topics) that were assessed as having a high degree of importance. Respondents were asked to classify the importance of each topic as "high", "medium", "low" or "unnecessary". We calculated importance indices for the topics based on the total number of respondents and weighted values of 100, 50, 25 and 0, respectively, for the degrees of importance. Where all respondents indicated "high" the index is 100, and where all indicated "unnecessary" it is 0. Unless otherwise specified, from now on all data used are from the second round questionnaire.

$$I_{index} = (100\ N_{high} + 50\ N_{medium} + 25\ N_{low}) / N_{all}$$

I_{index} : Degree of importance index

N_{high} : Number of "high" responses

N_{medium} : Number of "medium" responses

N_{low} : Number of "low" responses

N_{all} : Total number of degree of importance responses $(N_{high} + N_{medium} + N_{low} + N_{unnecessary})$

The average index for all topics is 62.1, slightly down from the 65.3 recorded in the fifth survey. By fields, environment has the highest average index with (72.0), followed by electronics (67.7) and life science (66.1), while the lowest is urbanization and construction with (56.0), then space (56.2).

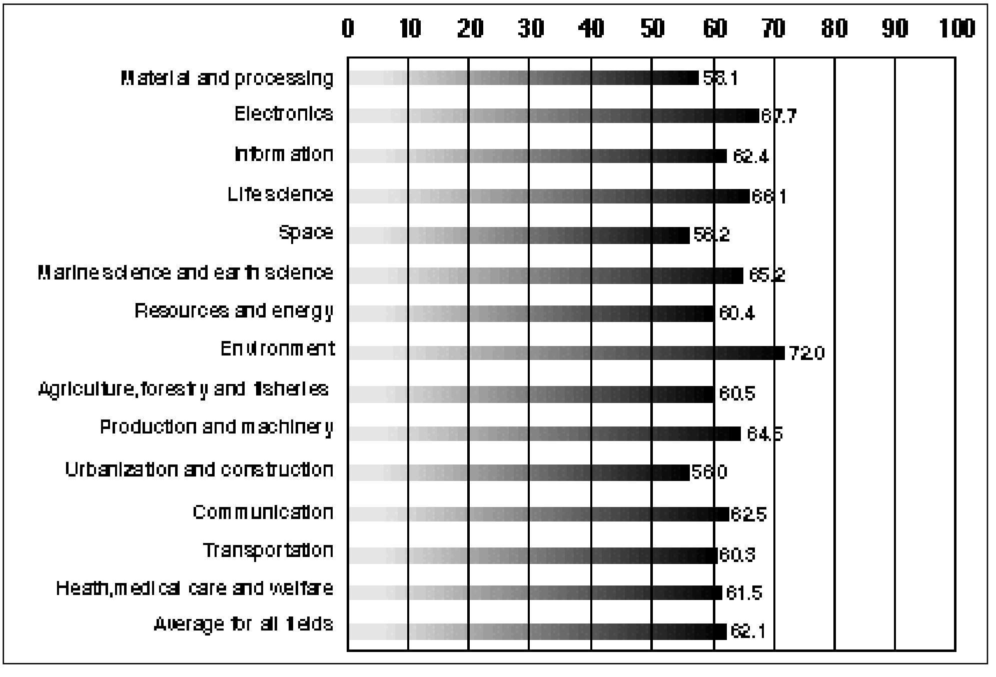


Fig. 1.1-1 Importance index by field.

Fields with the largest number of topics in the list of top 100 topics in degree of importance (see Table 1.1-1) are:

Electronics	15
Life science	13
Marine science and earth science	9
Environment	9
Materials and processing	8

From this we can see that while ìenvironmentî has the highest average index, it does not have the largest representation in the top 100 topics list. So although overall the environment is considered to be the most important field, relatively speaking there is not a large number of topics that are given particular prominence.

To determine any distinctive features about the top 100 topics in this survey, we compared them with the top 100 topics in the fifth survey.

First we divided the 100 topics into five classifications:

Environment-related technologies ranging from global environmental issues to local waste disposal

Information-related technologies such as memory and semiconductors, and the internet and other networks

Life-related technologies such as gene technology and treatment of illness

Disaster-related technologies such as prediction and prevention of earthquakes and other natural disasters

New energy technologies connected with the use of solar energy and other non-fossil fuel energy

This resulted in the following breakdown.

Classification	6th survey	5th survey
Environment-related technologies	25	28
Information-related technologies	24	10
Life-related technologies	17	37
Disaster-related technologies	11	9
New energy technologies	11	6
Others	12	10

What stands out here is that information-related technologies increased and life-related technologies decreased significantly. New energy technologies also recorded a considerable rise. Next we shall discuss the results for each classification in more detail.

Environment-related technologies

Overall, the number of topics has changed little, though the number connected with recycling, such as the greater acceptance of product design concepts that facilitate recycling and the practical use of technologies for recycling plastics has jumped from four in the fifth survey to nine in the sixth. On the other hand, topics related to the global environment, such as the practical use of CO2 fixing technology and fluorocarbon and halon substitutes, dropped from thirteen to seven, indicating that greater importance is given to the more familiar and tangible environmental technologies.

Information-related technologies

Network systems topics, such as practical use of a high-security next-generation internet and widespread use of networks that protect privacy and confidential information, jumped from two to twelve; and semiconductor-related topics, such as practical use of 256Gb memory chips and practical use of technology for mass production and processing of 10nm patterns, also jumped, from six to eleven. Thought to be behind these rises is a much greater awareness about the diversification of services and need for safety and security with the phenomenal rise in interest in the internet in Japan and throughout the rest of the world over the five years since the last survey.

Life-related technologies

While little change was seen in cancer-related topics, such as practical use of means of preventing the spread of cancer, dropping to nine from ten in the fifth survey, brain-related topics, such as treatment etc. of Alzheimer’s disease, dropped from eight to one this survey. This can be put down partly to the fact that the total number of related topics were consolidated from six topics in the previous survey, of which five made the top 100 list, to three topics in this survey. The number of topics dealing with the treatment of diseases such as arterial sclerosis also dropped. The average importance index value for the life science field was high in this survey as well, so the fact there were comparatively few life-related topics in the top 100 does not necessarily mean that the degree of importance fell, rather it should be seen to be attributed to the greater importance given to information technology.

Disaster-related technologies

The number of earthquake-related topics rose from four in the previous survey to eight in this survey, so overall the number of topics were up as well.

New energy technologies

Topics dealing with solar cell technology rose from two to four, and all are ranked in or near the top ten. There was little change in topics dealing with other technologies, such as nuclear power.

Table 1.1-1 Top 100 topics in the fifth survey

Rank-ing	Field	Topic	Degree of importance index	Forecasted realization time	Notes; Classification of topic	
1	Production	42 Widespread use of non-fossil energy sources (wind, geothermal, solar (photovoltaic / solar thermal) and waste heat) in all areas of life including household, industry and transportation.	94	2018	New energy	
2	Electronics	06 Practical use of VLSI with as much as 256 Gbits of memory per chip.	94	2014	Infor-mation	Semi-conductors etc.
3	Electronics	30 Practical use of solar cells which make the cost of power generation facilities less than 100 yen / watt.	93	2012	New energy	Solar cells
4	Electronics	05 Practical use of technology which allows mass processing of patterns with minimum line width as low as 10 nanometers.	93	2013	Infor-mation	Semi-conductors etc.
5	Space	25 The cost of rocket thrusted space transportation will be reduced to less than 1 / 10 current levels.	93	2014		
6	Production	50 Widespread use of designing, producing, collecting and recycling systems which make it possible to recycle most used materials through legally establishing manufacturers' responsibilities for collection and disposal of disused products.	92	2012	Environ-ment	Recycling
7	Marine science	60 Development of technology capable of forecasting the occurrence of major earthquakes (magnitude 7 or above) several days in advance.	92	2023	Disasters	Earth-quakes
8	Commu-nication	01 Practical use of a highly secure next-generation internet that allows the transmission of real-time information, leading to the implementation of internet-based telephone services and motion video broadcasts.	92	2003	Infor-mation	Networks
9	Electronics	18 Development of solar cells capable of maintaining 15% efficiency for at least 10 years without light convergence.	92	2010	New energy	Solar cells
10	Urbanization	13 Practical use in Japan of a safe and rational demolition technology for decommission of commercial nuclear power plants.	92	2009	New energy	Nuclear energy
11	Materials	84 Practical use of multi-layer solar cells with a conversion efficiency of more than 50%.	91	2016	New energy	Solar cells
12	Materials	85 Practical use of large-area amorphous silicon solar cells with a conversion efficiency of more than 20%.	91	2011	New energy	Solar cells
13	Life science	49 Practical use of effective means to prevent metastasis of cancer.	91	2013	Life	Cancer
14	Marine science	01 Practical use of Tsunami forecasting systems based on tide and Tsunami observation through satellites and on other data including shelf topography.	91	2007	Disasters	Natural disasters
15	Environ-ment	32 Wide acceptance of LCA-style product design concepts that encourage recycling and reuse.	91	2007	Environ-ment	Recycling

Table 1.1-1 Top 100 topics in the fifth survey. (Cont'd)

Ranking	Field	Topic	Degree of importance index	Forecasted realization time	Notes; Classification of topic	
16	Information	22 Widespread use of highly reliable network systems capable of protecting the privacy and secrecy of individuals and groups from the intrusion of ill-intentioned hackers.	91	2007	Information	Networks
17	Materials	34 Establishment and practical use of plastic recycling technology.	91	2007	Environment	Recycling
18	Production	44 Practical use of technologies that enable the direct storage of electricity (superconducting magnets, flywheels and capacitors).	90	2016	New energy	
19	Information	18 Realization of an environment in which the unlimited utilization of high-capacity networks (150 Mbps) for around 2,000 yen / month is possible.	90	2008	Information	Networks
20	Information	64 Establishment of social rules regarding multimedia copyrights, and expanded production and distribution of multimedia information.	89	2005	Information	Networks
21	Resources	63 Practical use of technology for the safe disposal of highly radioactives solid waste.	89	2019	New energy	Nuclear energy
22	Electronics	13 Practical use of TIPS (Tera Instruction Per Second) level microprocessors.	89	2018	Information	Semiconductors etc.
23	Environment	24 Widespread use of control technologies in virtually all types of automobiles, capable of meeting the emission control standard for nitric oxide at the order of 0.1 to 0.2 g / km. (The current level for heavy diesel motorcars is on the order of 4 to 5 g / km, and the standard control value for gasoline passenger cars in 1978 is 0.25 g / km.)	89	2007	Environment	
24	Electronics	08 Practical use of non-volatile, erasable with more than 100 Gbits capacity random access semiconductor memories.	88	2017	Information	Semiconductors etc.
25	Agriculture etc.	84 Practical use of a system of removing almost the entire pollution load on lakes, bays and other closed water bodies that are suffering from water quality degradation by developing environmental restoration technology that utilizes ecosystems and biological functions.	88	2018	Environment	
26	Transportation	31 Achievement of a 90% recyclability for motor vehicle parts and material (scrapped vehicles).	88	2009	Environment	Recycling
27	Marine science	14 Development of a numerical model of the correlation between climatic changes and changes in marine living resources.	88	2013	Environment	Global environment
28	Production	08 Practical use of room temperature superconductors in industrial products.	88	2016		
29	Resources	19 Practical use of economical methods for separating and recycling valuable substances in urban garbage.	88	2009	Environment	Recycling
30	Electronics	49 Production of household-use optical fiber signal tranceiver units at a cost of around 5,000 yen.	88	2009	Information	Networks

Table 1.1-1 Top 100 topics in the fifth survey. (Cont'd)

Ranking	Field	Topic	Degree of importance index	Forecasted realization time	Notes; Classification of topic	
31	Resources	17 Practical use of technologies capable of separating useful metals, such as iron, copper and aluminum, from metal-containing wastes, such as scrap cars, discarded electric appliances, to a purity level of more than 99%.	88	2011	Environment	Recycling
32	Life science	74 Identification and classification by the molecular etiology of the genes related to diabetes, hypertension, and arteriosclerosis, typical geriatric diseases which exhibit multiple-factor hereditary traits.	88	2012	Life	
33	Health	05 Elucidation of carcinogenic mutation mechanisms.	88	2013	Life	Cancer
34	Marine science	43 Establishment of scientific methods for long-range weather forecasting (1-6 months in advance).	88	2014		
35	Production	70 Widespread use of earthquake damage alleviation systems for industrial complexes, nuclear facilities, etc. based on the early operation of safety devices in response to initial mild tremors.	88	2009	Disasters	Earthquakes
36	Urbanization	05 Practical use in Japan of a mid-term (5 - 10 years in advance) prediction technique for large-scale (Magnitude 8 or stronger) earthquakes based on analyses of the distribution of strains in the earth's crust and past earthquake records.	87	2017	Disasters	Earthquakes
37	Transportation	07 Development of a system that detects the initial mild tremors of an earthquake at appropriate locations, and safely stops trains as necessary to avoid places that have a high risk of collapse (because of the earthquake).	87	2006	Disasters	Earthquakes
38	Electronics	09 Practical use of semiconductor LSIs that operate at a switching speed of 1 ps or less.	87	2015	Information	Semiconductors etc.
39	Agriculture etc.	02 Practical use in Japan of crop varieties having the characteristics (higher yield and more disease- and cold-resistance) improved by gene manipulation.	87	2004	Life	
40	Life science	48 Development of drugs capable of preventing the occurrence of certain types of cancer.	87	2010	Life	Cancer
41	Production	51 Advancements in technological development such as carbon dioxide recovery and detoxification of harmful wastes, leading to the widespread use of global environmental conservation measures throughout the world.	87	2018	Environment	Global environment
42	Communication	72 Development of high performance batteries with an energy density of about 500 Wh/kg, capable of miniaturizing mobile phones in terms of both size and weight.	87	2009		
43	Information	48 Widespread use in all areas of security systems capable of providing emergency information to the general public in the case of a disaster.	87	2007	Disasters	

Table 1.1-1 Top 100 topics in the fifth survey. (Cont'd)

Ranking	Field	Topic	Degree of importance index	Forecasted realization time	Notes; Classification of topic	
44	Environment	34 Establishment of assessing socio-economic damage/loss because of the destruction of natural environment by soil contamination and land subsidence (e.g., loss of natural beaches, forests, or fields) and incorporation of its countermeasures in regulatory system.	87	2012	Environment	
45	Health	44 Improvement in the average five-year survival rate for all types of cancer to more than 70% (currently about 40% for stomach cancer).	87	2013	Life	Cancer
46	Electronics	19 Development of processor LSIs with 10 GIPS performance and power consumption of 10 miliwatts or less.	87	2014	Information	Semiconductors etc.
47	Life science	02 Development of anti-cancer agents which target the manifestation functions of cancer genes.	87	2010	Life	Cancer
48	Life science	35 Widespread production of bioplastics using microorganisms and plants, accounting for 10% of the total volume of worldwide plastic production.	87	2013	Environment	Recycling
49	Agriculture etc.	01 Elucidation of the whole DNA sequences of crops (e.g. Rice) to isolate useful genes.	87	2009	Life	
50	Agriculture etc.	20 Widespread use of biodegradable containers and wrapping materials that use bio-oriented materials.	86	2005	Environment	Recycling
51	Marine science	45 Nationwide installation of bore-hole-type observation equipment integrating various types of gauges (e.g., seismometers, tiltmeters, and strain-gauges) for use in earthquake forecasting.	86	2011	Disasters	Earthquakes
52	Life science	01 Identification of multiple genes related to cancer, and elucidation of the relationships between those genes and carcinogenesis.	86	2014	Life	Cancer
53	Health	06 Elucidation of cancer metastasis mechanisms.	86	2012	Life	Cancer
54	Life science	67 Become possible to cure senile dementia of Alzheimer type.	86	2016	Life	Brain
55	Production	49 Widespread use of low entropy-generating eco-factories, which give due consideration to the impact on local ecosystems throughout product life cycles, from manufacture to disposal.	86	2017	Environment	Recycling
56	Marine science	58 Practical use of technology for predicting and forecasting landslides and rockslides caused by intense rainfall in certain locations in Japan.	86	2010	Disasters	Natural disasters
57	Communication	63 Practical use of integrated building management systems and home security systems which are linked to an earthquake detection system and take the necessary safety measures to protect human lives in the event of a non-direct-hit earthquake, taking advantage of the time lag to the arrival of seismic waves.	86	2011	Disasters	Earthquakes
58	Materials	62 Development of memory capacity of 1 terabit per chip.	86	2013	Information	Semiconductors etc.

Table 1.1-1 Top 100 topics in the fifth survey. (Cont'd)

Ranking	Field	Topic	Degree of importance index	Forecasted realization time	Notes; Classification of topic	
59	Urbanization	04 Development of a nationwide network for detecting earthquakes, and widespread use in Japan of a disaster prevention system that gives advance warning of earthquakes at a distance of at least 50Km.	86	2011	Disasters	Earth-quakes
60	Life science	91 Development of technologies which dramatically improve photosynthetic ability in order to increase food production.	86	2017	Life	
61	Transportation	17 Widespread use of motor vehicles with fuel efficiencies 30% greater than today's vehicles through the introduction of new materials that increase strength and reduce weight and development of element technologies such as one concerning engine thermal efficiency improvements.	86	2007	Environment	
62	Environment	38 Widespread use (e.g., more than 10% in the world) of automobiles as urban transportation system (e.g., electric vehicles) which do not cause air or noise pollution.	86	2013	Environment	
63	Communication	67 Widespread use of electronic commerce carried out via a network based on an electronic funds transfer system and electronic money system.	85	2006	Environment	Networks
64	Materials	107 Practical use of processes for water decomposition by the sunlight.	85	2017	New-energy	
65	Environment	23 Introduction of environment tax aiming at global environmental conservation.	85	2006	Environment	Global environment
66	Information	05 Practical use of systems which facilitate multimedia communication from anywhere in the world using pocket-size computers.	85	2003	Information	Networks
67	Marine science	12 Practical use of technologies for predicting and forecasting changes in the ocean currents in the seas adjoining Japan.	85	2011		
68	Agriculture etc.	55 Development of production regulation systems as a step toward management of resources and fisheries once it becomes possible to predict the long term (10 to 20 years) changes major fishery resources.	84	2016		
69	Electronics	24 Widespread use of a portable multimedia wireless terminal operated on the order of 100 Mbits/sec., which can be used throughout the world.	84	2011	Information	Networks
70	Materials	108 Practical use of carbon dioxide fixation technology necessary for protecting global environments.	84	2016	Environment	Global environment
71	Space	09 Realization of precision down to less than a centimeter in measurement of crustal movement using VLBI (very long baseline inter-ferometers), satellite lasers, inverse laser ranging, and synthetic aperture radar to improve accuracy in such as earthquake forecasting.	84	2009	Disasters	Earth-quakes

Table 1.1-1 Top 100 topics in the fifth survey. (Cont'd)

Rank ing	Field	Topic	Degree of importance index	Forecasted realization time	Notes; Classification of topic	
72	Transportation	30 Practical use of heavy-duty freight truck exhaust clean-up technologies - such as diesel exhaust catalysts, particulate traps, lean-burn NOx catalysts and high precision combustion technology - to reduce the harmful components of exhaust to 1/10 of present levels.	84	2010	Environment	
73	Transportation	14 Widespread use of traffic control systems on road, for optimal control of the flow of traffic in cities based on identification of vehicles on road, speed, and level of congestion.	84	2007		
74	Communication	08 Development of a super high-speed computer communication protocol capable of achieving a throughput of hundreds of Mbps.	84	2003	Information	Networks
75	Electronics	32 Practical use of ultraviolet, blue, and green, semiconductor lasers.	84	2004		
76	Environment	08 Determination and general understanding of the impact of global warming on world agricultural production.	83	2012	Environment	Global environment
77	Materials	44 Development of superconductive materials with a transition temperature around room temperature.	83	2020		
78	Life science	72 Scientific elucidation of the factors within daily life (eating habits, air quality, etc.) which influence the process of carcinogenesis.	83	2012	Life	Cancer
79	Information	45 Advances in software inspection and verification technology, enabling quick development of error-free, large-scale software.	83	2012	Information	
80	Marine science	22 Development of safe, economically feasible technology for the removal/detoxification of sea-bottom sludges, enabling the widespread application of methods for decontamination and recovery of fishery grounds.	83	2013	Environment	
81	Electronics	67 Development of a magnetic memory hard disk capable of recording 1,000 Gbits density per square inch.	83	2017	Information	Semiconductors etc.
82	Agriculture etc.	42 Establishment of a quantitative assessment technique for the environmental conservation functions of forest ecosystems, and widespread use of a forest management technique that makes the exploitation of timber resources, while still maintaining such functions.	83	2014	Environment	
83	Urbanization	62 Establishment in Japan of a wide-area integrated water management technique covering rivers, dammed reservoirs, etc., leading to widespread use of efficient water resource utilization systems in major urban zones.	83	2009		
84	Electronics	38 Practical use of optical multiplexed communication equipment capable of multiplexing 200 channels of signals with 100 Gbits/sec. and transmitting them over a single optical fiber.	83	2014	Information	Networks
85	Resources	06 Development of a steelmaking technology that requires fossil fuel consumption less than half of the present level.	83	2014		

Table 1.1-1 Top 100 topics in the fifth survey. (Cont'd)

Rank ing	Field	Topic	Degree of importance index	Forecasted realization time	Notes; Classification of topic	
86	Life science	52 Development of an entirely implantable artificial kidney.	83	2013	Life	
87	Commu-nication	09 Widespread use of integrated information wiring and plug socket that incorporate services such as the telephone, Internet, VOD and high-definition TV in homes and offices.	83	2007	Infor-mation	Networks
88	Life science	28 Control of signal transduction in the carcinogenesis of cells, and widespread use of treatment methods for dysdifferentiating carcinogenic cells.	82	2020	Life	Cancer
89	Environment	31 Widespread use of power generation using refuse derived fuel (RDF).	82	2006	New energy	
90	Electronics	68 Practical use of optical memories with recording density of 1011 b / cm2.	82	2016	Infor-mation	Semicon-ductors etc.
91	Commu-nication	74 Practical use of biochip devices that have a memory density (1012 bit / cm2) 1,000 times that of current semiconductor devices (109 bits / cm2).	82	2015	Infor-mation	Semicon-ductors etc.
92	Marine science	17 Practical use of systems for monitoring water pollution on a global scale.	82	2012	Environ-ment	Global environ-ment
93	Electronics	28 Practical use of automated production systems in which LSI chips are produced automatically by giving LSI design data.	82	2015	Infor-mation	Semicon-ductors etc.
94	Life science	07 Elucidation of the environmental factors and control mechanisms of the immune response which triggers allergies such as hay fever and atopy, facilitating the complete control over immediate type hyper-sensitivity.	82	2014	Life	
95	Infor-mation	68 Widespread use of systems to unitarily handle information management (orders, design, manufacturing, maintenance) among related companies.	82	2005	Infor-mation	Networks
96	Environ-ment	04 Practical use of materials that replace fluorocarbons and halons, that do not damage the ozone layer and cause global warning problem.	82	2007	Environ-ment	Global environ-ment
97	Materials	20 Practical use of rechargeable polymer batteries having a volume-specific capacity of 400 Wh / liter. (Capacity of current Ni-Cd batteries: 180 Wh / liter)	82	2011		
98	Environment	27 Widespread use, including use at home, of compact waste-water treatment systems based on biotechnology for the highly efficient treatment of persistent substances and hazardous materials.	82	2010	Environ-ment	
99	Life science	36 Widespread production of alcohol and other fuel oils utilizing microorganisms, seaweed, etc., accounting for 10% of total worldwide fuel oil production.	81	2015	New energy	
100	Health	20 Widespread use of scientific guidelines for adult-disease-preventing life-styles (nutrition, rest and exercise).	81	2006	Life	

2. Major technological trends in expected effect

This survey examines the kind of effect expected from each of the topics. Specifically, respondents were asked to choose from the following four items for each topic.

- Contribution to socioeconomic development
- Resolution of various problems of a global scale
- Response to people's needs
- Expansion of human intellectual resources

2.1 Trends in each field

Figure 2.1-1 shows the average topic response rate for the above items by field. The average value for all topics is quite high in contribution to socioeconomic development and response to people’s needs, and low in expansion of human intellectual resources.

Fields with a high number of topics considered to make a high contribution to socioeconomic development are “electronics” (77.6), “communication” (71.8), “materials” (69.6), “production” (67.0) and “information” (64.2); these fields also have a high number of topics thought to make only a minor contribution to resolution of global problems. Conversely, fields expected to make a high contribution to the resolution of global problems are “environment” (81.6), “resources” (78.7), “agriculture etc.” (65.0) and “marine science” (57.6).

As for response to people’s needs, “health” is extremely high at 92.0%, while those with a comparatively high expectation are “information” (59.7), “urbanization” (59.0), “communication” (57.2), “transportation” (52.0) and “life science” (50.4). As

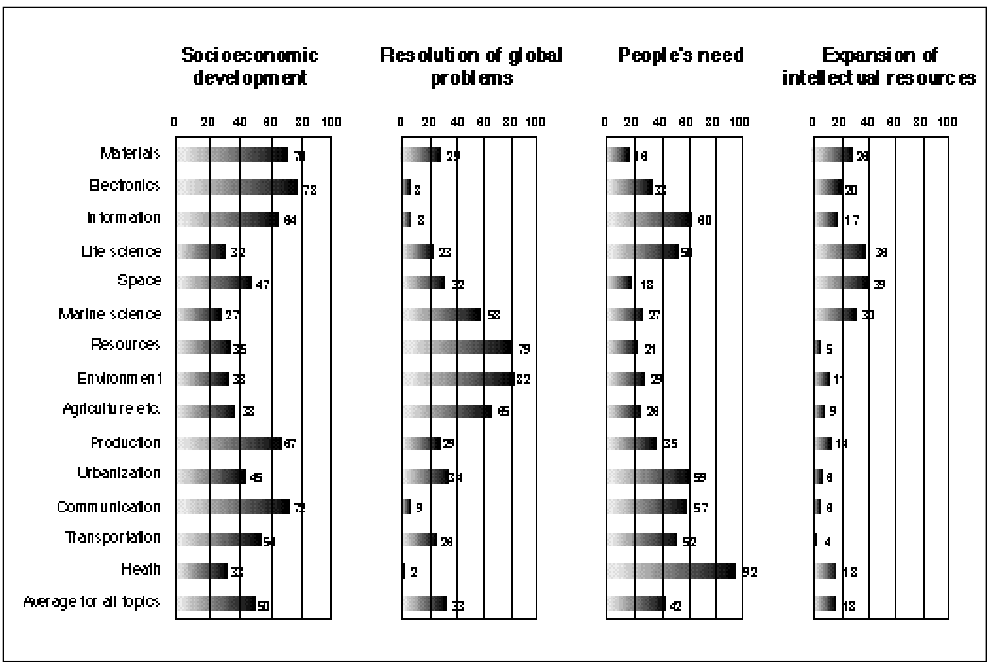


Fig. 2.1-1 Trends in expected effect (by field).

for expansion of intellectual resources, no field exceeded 50%, but those with comparatively high reading are “space” (39.0), “life science” (36.3) and “marine science” (29.8).

2.2 Trends in forecasted realization time

To examine trends in topics considered to have a particularly high effect on socioeconomic development etc., we looked at topics that at least 80% of respondents believe would have an effect on an item and that are considered to have a relatively high degree of importance (topics with a degree of importance index of at least 80 for “socioeconomic development,” “resolution of global problems” and “response to people’s needs,” and at least 50 for “expansion of intellectual resources”; hereinafter referred to as important topics with a high expected effect).

Topics with a high expectation in “contribution to socioeconomic development”

Fields with a high number of topics thought to deliver a significant effect are “information,” “communication” and “electronics.” It is thought that from 2001 to 2010 advances made in network-related technology will have a significant impact. In the ten years from 2011, technology for mass production and processing of microscopic patterns and technologies revolving around devices such as high-speed processors and high-capacity memory chips will steadily move ahead, and the economic effects of these technologies is expected to be substantial.

Topics with a high expectation in “resolution of various problems of a global scale”

Until 2005 there is not expected to be any significant advancement, but from 2006 to 2015 recycling of plastics, motor vehicles and the like is expected to be firmly established. Meanwhile, motor vehicle pollution is expected to drop, with a reduction of nitrogen oxides in vehicle exhausts, lower exhaust emissions by large trucks, and the widespread use of electric cars. Advances are also expected in the development of environmental monitoring systems as a global approach to environmental issues, such as a real-time global monitoring network and a world-wide marine pollution monitoring system.

Topics with a high expectation in “response to people’s needs”

There is an especially large number of topics with a high expected effect in “life science,” followed by “urbanization.” Advances are expected in forecasting disasters and systems for transmitting disaster information by about 2010, and after 2010 developments are expected in the elucidation and treatment of cancer mechanisms. As for predicting earthquakes, 2016-2020 for magnitude 8 earthquakes and after 2020 for magnitude 7 earthquakes is the general line of thought.

Topics with a high expectation in “expansion of intellectual resources”

Fields with a large number of topics with a high expected effect are “life science” and “space”. Advances are expected in gene-level analysis of cells by about 2010, and 2011-2015 in the elucidation of the human memory structure and the mechanism by which neural networks are formed. Based on these advances, progress is expected in the elucidation of the mechanisms of human logical reasoning and creation from 2021.

2.3 Relationship with measures the government should adopt

Figure 2.3-1 shows in graph form the effective measures respondents believe the government should adopt for topics with a high expected effect.

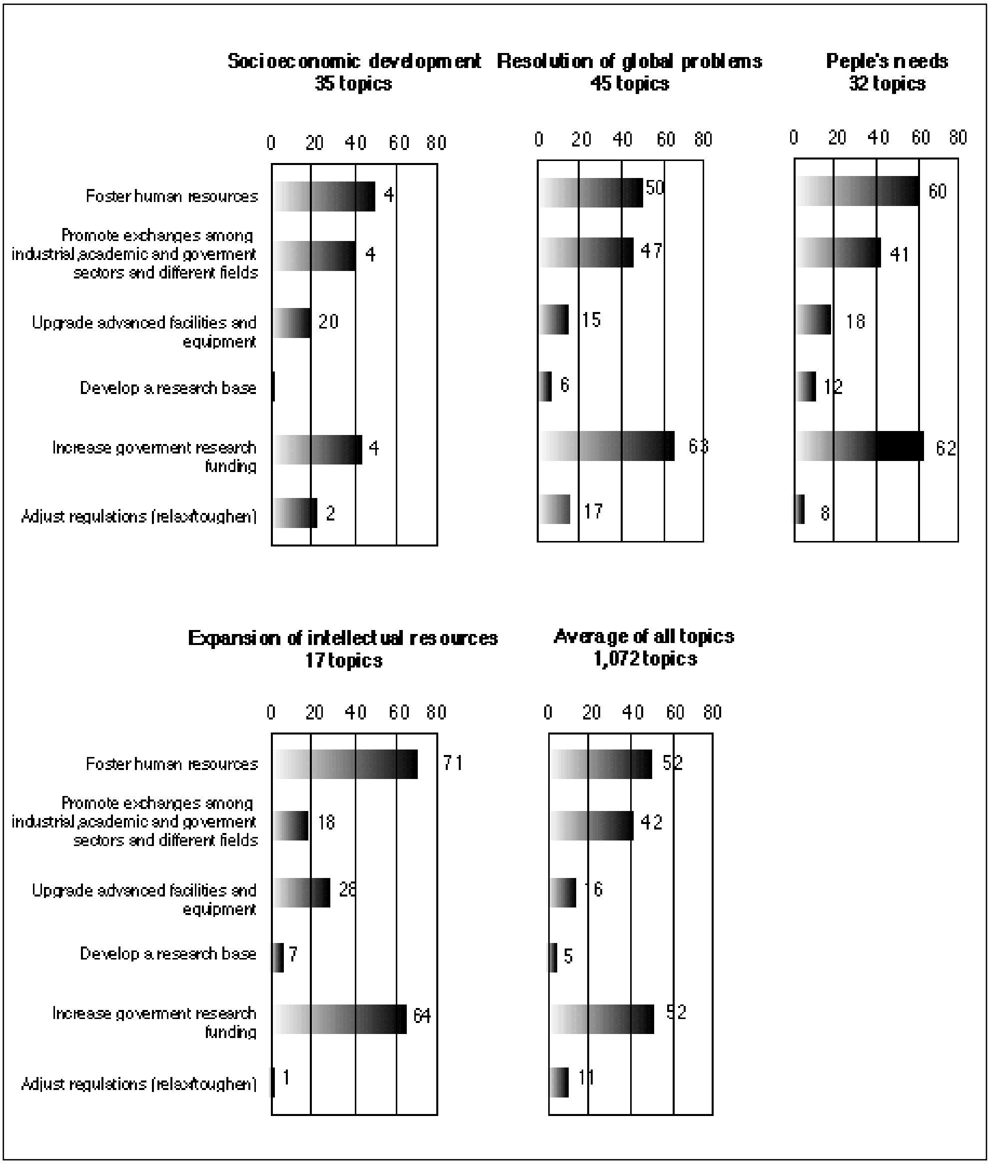


Fig. 2.3-1 Expected effect and effective measures the government should adopt.

For topics with a high expected effect in “socioeconomic development,” “foster human resources,” “increase government research funding” and “promote exchanges among industrial, academic and government sectors and different fields” are ranked the highest, but all are below their respective averages for all topics. In contrast, a greater proportion of respondents want the government to “adjust regulations (relax/toughen)” than the average. Typical examples of this are topics related to multimedia and networks, such as “603066: Widespread use of electronic money to settle monetary matters” (adjust regulations (relax/toughen) ó 84%), and “603064: Establishment of social rules regarding multimedia copyrights” (adjust regulations (relax/toughen) — 83%).

As for "resolution of global problems," the percentage calling on the government to "promote exchanges among industrial, academic and government sectors and different fields," "increase government research funding" and "adjust regulations (relax/toughen)" are higher than their respective averages for all topics, especially government funding, which is 11% higher than its overall average. Typical examples include topics related to the management and assessment of the environment and biological resources, such as "609084: Practical use of a system of removing almost the entire pollution load caused by environmental degradation on closed water bodies" (increase government research funding — 78%), and "609054: Development of an estimation technique for an optimum fisheries production level for each fishing area based on simulation techniques for biological propagation" (increase government research funding — 78%).

In the "response to people's needs" item, "foster human resources" and "increase government research funding" are especially high. "Develop a research base" is also higher than its averages for all topics. Topics for which the voices calling for greater government spending are loudest are those connected with earthquakes, including "612063: Practical use of integrated building management systems linked to an earthquake detection system" (increase government research funding — 78%) and "611004: Widespread use in Japan of a disaster prevention system that gives advance warning of earthquakes at a distance of at least 50km" (increase government research funding — 74%).

Regarding the "expansion of intellectual resources," percentages for "foster human resources" and "increase government research funding" are quite high, while "upgrade advanced facilities and equipment" is also above its all-topics average. "Foster human resources" is very high at 71%, and specific examples include topics connected with the elucidation of life phenomena, such as "604041: Elucidation of relationships between higher-order structures and functions of the nuclei in eukaryotic cells" (82%) and "604084: Complete elucidation of the molecular mechanisms of development and differentiation" (82%).

2.4 Relationship with potential problems

Figure 2.4-1 shows in graph form concerns respondents have with the realization of topics with a high expected effect.

Respondents expressed a higher-than-average concern over the "adverse effect on safety" regarding topics with a high expected effect in "contribution to socioeconomic development," which include many network- and device-related topics, as can be seen by "603066: Widespread use of electronic money to settle monetary matters" (67%) and "612067: Widespread use of electronic commerce carried out via a network" (67%).

As for topics with a high expected effect in "resolution of global problems," respondents expressed considerable concern over the "adverse effect on the natural environment" regarding technologies connected with nuclear power, such as "611013: Practical use in Japan of a safe and rational technology for decommission of commercial nuclear power plants" (70%) and "607063: Practical use of technology for the safe disposal of highly radioactive solid waste" (54%), and technologies connected with improving crop quality through gene manipulation, such as "609002: Practical use in Japan of crop varieties improved by gene manipulation" (60%) and "604091: Development of technologies which dramatically improve photosynthetic ability in order to increase food production" (47%).

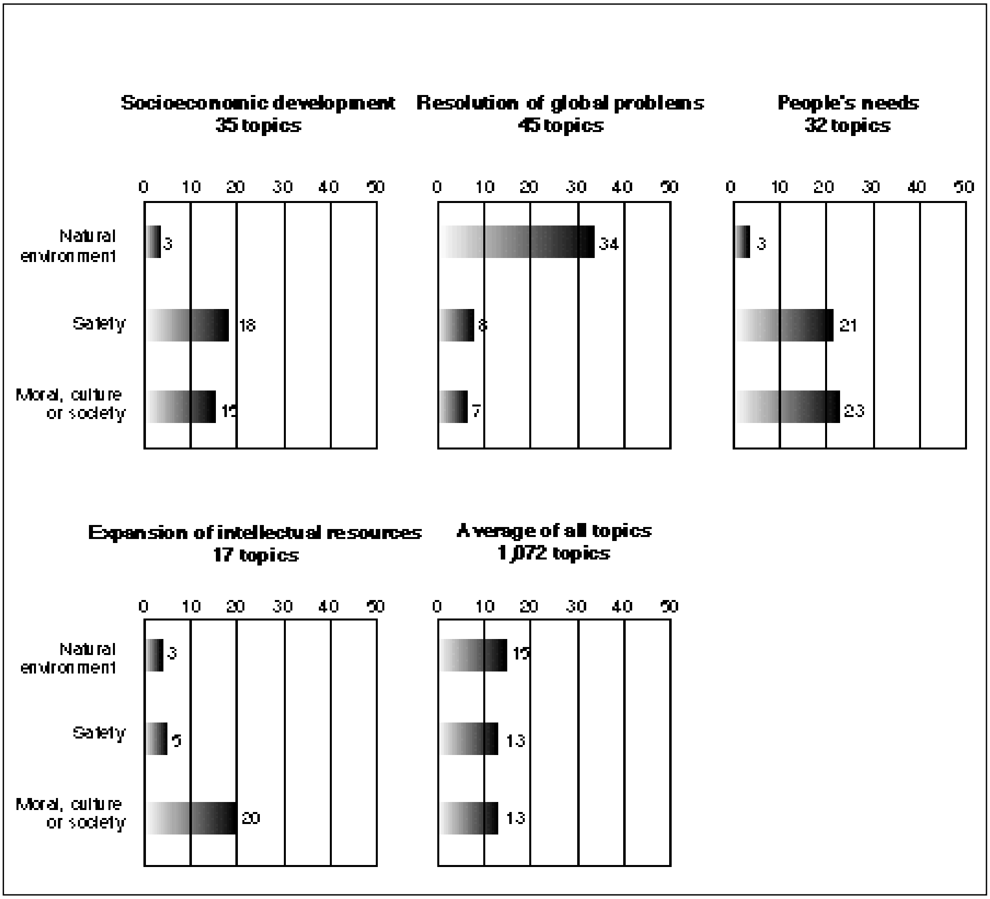


Figure 2.4-1 Expected effect and potential problems.

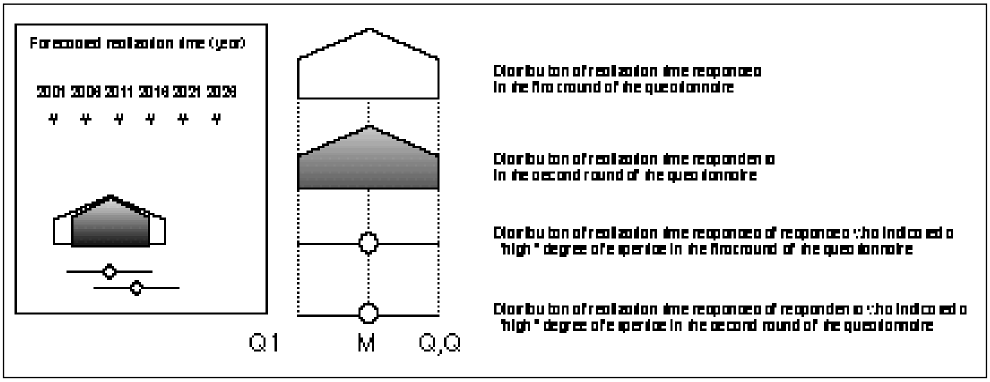
Regarding "response to people's needs," higher-than-average concern was expressed over "adverse effect on safety" and "adverse effect on morals, culture or society." Topics that attracted a high response rate on "adverse effect on safety" include "611001: Widespread use in Japan of warning systems etc. based on localized weather forecasts" (52%) and "611003: Development of disaster forecasting and information transmission systems to prevent panic during an earthquake" (50%), while those attracting a high response rate on "adverse effect on morals, culture or society" include "614020: Widespread use of scientific guidelines for adult-disease-preventing life-styles (nutrition, rest and exercise)" (54%), "604001: Identification of multiple genes related to cancer, and elucidation of the relationships between those genes and carcinogenesis" (49%), and "614005: Elucidation of carcinogenic mutation mechanisms" (45%).

As for topics with a high expected effect in "expansion of intellectual resources," the response rate for "adverse effect on morals, culture or society" was higher than its average for all topics; specific examples include topics connected with the elucidation of life phenomena, such as "604019: Elucidation of the molecular mechanism of life creation" (45%), and "604023: Elucidation of the transcription cascade for all genes, from fertilized egg to individual, in a single higher animal species, e.g. mice, and the mechanism by which differentiation and functions are manifest" (44%).

3. Trends in forecasted realization time

3.1 Overall trends

Figure 3.1-1 shows the distribution of forecasted realization times of all 1,072 topics, and Table 3.1-1 shows the average forecasted realization time and the average range of forecasted times for each field. Here the “range of forecasted times” is the width between Q1 (forecasted realization year of the response at the 25th percentile of all responses) and Q2 (forecasted realization year of the response at the 75th percentile of all responses). A narrow width (responses from the half of all respondents who were positioned around the middle value) represents a strong consensus among respondents. The survey forecasts technologies up to the year 2025, so the questionnaires gave respondents realization time choices of five-year increments to 2025, after which the time was left open with “2026-”. Consequently, Table 3.1-1 omits any topics for which Q2 in the second round questionnaire (R2) is after 2026.



A mere 4.2% of topics (45 topics) are forecasted to be realized by 2005. And as shown in Figure 3.1-1, the “information” and “communication” fields have the largest proportions of these topics. In the five years between 2006 and 2010 and also between 2011 and 2015, respectively 37.1% (398 topics) and 38.0% (407topics) of topics are expected to be realized, so over this ten-year period respondents forecast that 75.1% (805topics) of all topics will be realized.

By fields, trends show us that “information” and “communication” contain many topics likely to be realized relatively early, whereas at the opposite end of the scale, “resources and energy” and “life science” have many topics that will be realized much later. Respondents forecast that 20.7% (222topics) of topics will be realized after 2016, and the highest percentage of these are in the “life science” and ìresources and energyî fields.

The range of forecasted times is narrow in the “communication,” “transportation” and “information” fields where the forecasted realization time is relatively early, and broader in the “life science” and “resources and energy” fields where realization is expected to be later.

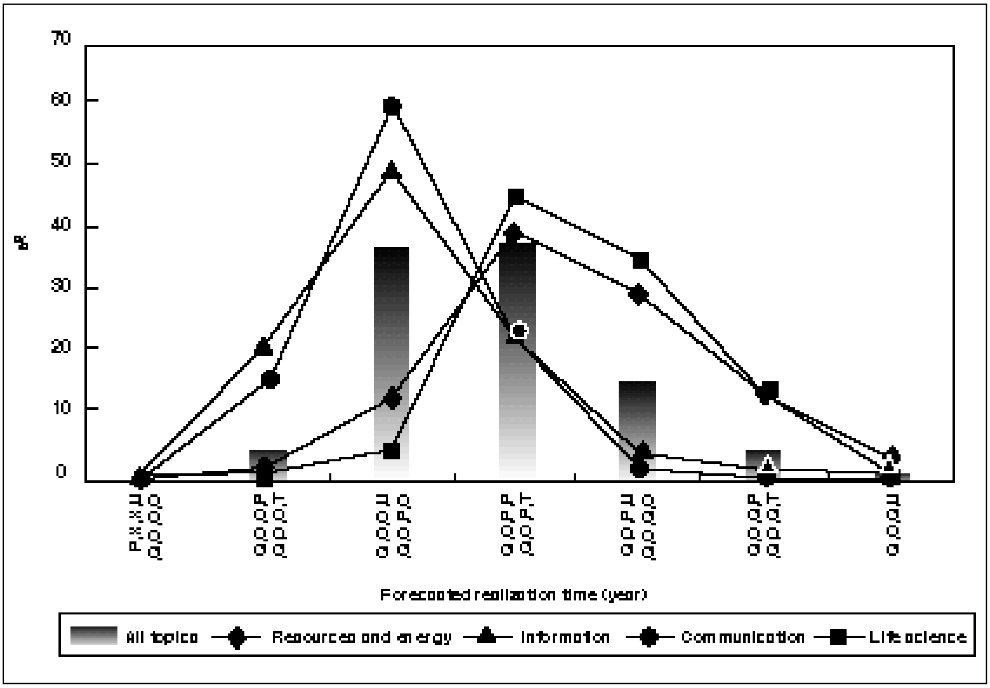


Fig. 3.1-1 Trends in forecasted realization time.

Table 3.1-1 Forecasted realization time and range of forecasted times.

999 topics

Field	Forecasted realization time (year)	Range of forecasted times (years)
Materials	2012.3	8.5
Electronics	2013.7	8.7
Information	2009.1	7.4
Life science	2015.3	9.8
Space	2011.8	7.2
Marine science	2011.5	8.9
Resources	2014.6	9.0
Environment	2012.0	8.4
Agriculture etc.	2011.0	7.9
Production	2012.4	7.5
Urbanization	2010.7	7.6
Communication	2009.0	6.6
Transportation	2010.2	7.1
Health	2012.2	9.3
Average all topics	2011.9	8.2

3.2. Chronological table of technology forecast

Year	Field		Topic
2002	Transportation	10	Practical use of driving simulators that enable a learner driver to have a realistic experience of driving under extreme conditions and being involved in a traffic accident (realistically simulates impact or inertia).
2003	Communication	01	Practical use of a highly secure next-generation internet that allows the transmission of real-time information, leading to the implementation of internet-based telephone services and motion video broadcasts.
	Information	05	Practical use of systems which facilitate multimedia communication from anywhere in the world using pocket-size computers.
2004	Electronics	32	Practical use of ultraviolet, blue, and green, semiconductor lasers.
	Agriculture etc.	02	Practical use in Japan of crop varieties having the characteristics (higher yield and more disease- and cold-resistance) improved by gene manipulation.
2005	Information	64	Establishment of social rules regarding multimedia copyrights, and expanded production and distribution of multimedia information.
	Agriculture etc.	20	Widespread use of biodegradable containers and wrapping materials that use bio-oriented materials.
2006	Communication	67	Widespread use of electronic commerce carried out via a network based on an electronic funds transfer system and electronic money system.
	Transportation	07	Development of a system that detects the initial mild tremors of an earthquake at appropriate locations, and safely stops trains as necessary to avoid places that have a high risk of collapse (because of the earthquake).
	Environment	23	Introduction of environment tax aiming at global environmental conservation.
	Environment	31	Widespread use of power generation using refuse derived fuel (RDF).
	Health	20	Widespread use of scientific guidelines for adult-disease-preventing life-styles (nutrition, rest and exercise).
2007	Materials	34	Establishment and Practical use of plastic recycling technology.
	Information	22	Widespread use of highly reliable network systems capable of protecting the privacy and secrecy of individuals and groups from the intrusion of ill-intentioned hackers.
	Environment	04	Practical use of materials that replace fluorocarbons and halons, that do not damage the ozone layer and cause global warningproblem.
	Transportation	14	Widespread use of traffic control systems on road, for optimal control of the flow of traffic in cities based on identification of vehicles on road, speed, and level of congestion.
	Space	05	Development of technology for measuring, in real time, the distribution and movement of air pollution via observation from space.
	Health	13	Development of an HIV vaccine.
2008	Communication	66	Widespread use of on-line seal-less document preparation services for various official documents such as contract documents which are provided via a network based on security technology capable of achieving both privacy protection and verification.
	Space	02	Widespread use of a global-scale environmental surveillance network in which environmental changes for the earth as a whole are monitored around the clock in real time, and this information is integrated, systematically analyzed, and distributed around the world.
	Marine science	69	Inauguration in Japan of global science and technology educational organizations in the broad sense, in order to foster international scientists and technologists contributing to conservation of the global environment, development and maintenance of global resources, etc.
	Agriculture etc.	09	Widespread use of the pest control method based mainly on the biological insecticides (natural microbial enemies, pheromones, etc.).
2009	Transportation	55	Practical use of floating off-shore airports.
	Health	36	Practical use of anti-AIDS therapy.
	Production	70	Widespread use of earthquake damage alleviation systems for industrial complexes, nuclear facilities, etc. based on the early operation of safety devices in response to initial mild tremors.

3.2. Chronological table of technology forecast (Cont'd)

Year	Field		Topic
	Space	09	Realization of precision down to less than a centimeter in measurement of crustal movement using VLBI (very long baseline inter-ferometers), satellite lasers, inverse laser ranging, and synthetic aperture radar to improve accuracy in such as earthquake forecasting.
	Urbanization	13	Practical use in Japan of a safe and rational demolition technology for decommission of commercial nuclear power plants.
	Electronics	49	Production of household-use optical fiber signal tranceiver units at a cost of around 5,000 yen.
	Urbanization	29	Spread of community-based efforts to utilize unused energy sources and recycle household wastes etc. in Japan.
	Resources	19	Practical use of economical methods for separating and recycling valuable substances in urban garbage.
	Transportation	31	Achievement of a 90% recyclability for motor vehicle parts and material (scrapped vehicles).
2010	Space	16	Full-scale operation of a space station as a laboratory on the low earth orbit, and realization of next-generation facilities using the space environment for research, development, and trial production of semiconductors, pharmaceuticals, etc.
	Production	17	Impact of engineering techniques that control silicon microscopic structures (to choose desired atomic and molecular arrangements at will) felt in all aspects of the production and machinery area.
	Electronics	18	Development of solar cells capable of maintaining 15% efficiency for at least 10 years without light convergence.
	Marine science	13	Development of technologies based on large-scale numerical models for forecasting changes in the global oceans.
	Marine science	58	Practical use of technology for predicting and forecasting landslides and rockslides caused by intense rainfall in certain locations in Japan.
	Environment	27	Widespread use, including use at home, of compact waste-water treatment systems based on biotechnology for the highly efficient treatment of persistent substances and hazardous materials.
	Transportation	30	Practical use of heavy-duty freight truck exhaust clean-up technologies - such as diesel exhaust catalysts, particulate traps, lean-burn NOx catalysts and high precision combustion technology - to reduce the harmful components of exhaust to 1/10 of present levels.
2011	Life science	04	Development of methods for surmising new functions of proteins from human genome information.
	Environment	29	Development of low-noise engines and tires, and sound-absorbing construction materials, leading to the reduction of automobile noise within the environmental standard for the area specified to be for resident.
	Environment	05	Elucidation of the accurate mechanism of carbon dioxide generation and absorption.
	Resources	17	Practical use of technologies capable of separating useful metals, such as iron, copper and aluminum, from metal-containing wastes, such as scrap cars, discarded electric appliances, to a purity level of more than 99%.
	Health	09	Elucidation of the arteriosclerosis contraction mechanisms.
	Urbanization	04	Development of a nationwide network for detecting earthquakes, and widespread use in Japan of a disaster prevention system that gives advance warning of earthquakes at a distance of at least 50km.
2012	Environment	34	Establishment of assessing socio-economic damage/loss because of the destruction of natural environment by soil contamination and land subsidence (e.g., loss of natural beaches, forests, or fields) and incorporation of its countermeasures in regulatory system.
	Production	50	Widespread use of designing, producing, collecting and recycling systems which make it possible to recycle most used materials through legally establishing manufacturers' responsibilities for collection and disposal of disused products.
	Health	06	Elucidation of cancer metastasis mechanisms.

3.2. Chronological table of technology forecast (Cont'd)

Year	Field		Topic
	Communication	38	Development of an automatic Japanese-English, English-Japanese speech translation telephone system comparable to human simultaneous interpretation in service quality.
	Electronics	30	Practical use of solar cells which make the cost of power generation facilities less than 100 yen / watt.
2013	Health	05	Elucidation of carcinogenic mutation mechanisms.
	Life science	35	Widespread production of bioplastics using microorganisms and plants, accounting for 10% of the total volume of worldwide plastic production.
	Resources	81	Widespread use of electric vehicles with driving performance equal to that of gasoline motorcars.
	Electronics	05	Practical use of technology which allows mass processing of patterns with minimum line width as low as 10 nanometers.
	Marine science	14	Development of a numerical model of the correlation between climatic changes and changes in marine living resources.
	Health	44	Improvement in the average five-year survival rate for all types of cancer to more than 70% (currently about 40% for stomach cancer).
	Health	48	Practical use of effective methods against cancer metastasis.
	Life science	49	Practical use of effective means to prevent metastasis of cancer.
	Health	53	Development of effective methods of preventing Alzheimer’s disease.
2014	Life science	01	Identification of multiple genes related to cancer, and elucidation of the relationships between those genes and carcinogenesis.
	Marine science	43	Establishment of scientific methods for long-range weather forecasting (1-6 months in advance).
	Resources	06	Development of a steelmaking technology that requires fossil fuel consumption less than half of the present level.
	Materials	49	Widespread use of industrial electric machines which employ superconductive materials having a critical temperature of liquid nitrogen (77 K) or more.
	Space	25	The cost of rocket thrusted space transportation will be reduced to less than 1 / 10 current levels.
	Electronics	06	Practical use of VLSI with as much as 256 Gbits of memory per chip.
2015	Information	49	Practical use of robots capable of recognizing, finding, and rescuing humans involved in a disaster.
	Life science	51	Practical use of artificial organs (pancreases, kidneys, livers, etc.) incorporating human cells and tissues.
	Electronics	09	Practical use of semiconductor LSIs that operate at a switching speed of 1 ps or less.
	Life science	36	Widespread production of alcohol and other fuel oils utilizing microorganisms, seaweed, etc., accounting for 10% of total worldwide fuel oil production.
	Communication	74	Practical use of biochip devices that have a memory density (1012 bit / cm2) 1,000 times that of current semiconductor devices (109 bits / cm2).
2016	Materials	84	Practical use of multi-layer solar cells with a conversion efficiency of more than 50%.
	Urbanization	20	Widespread use in Japan of active environmental clean-up facilities that absorb and fix air pollutants such as CO2, NOx and freons in urban areas, where the majority of emissions occur.
	Agriculture etc.	55	Development of production regulation systems as a step toward management of resources and fisheries once it becomes possible to predict the long term (10 to 20 years) changes major fishery resources.
	Production	44	Practical use of technologies that enable the direct storage of electricity (superconducting magnets, flywheels and capacitors).
	Materials	109	Widespread use of desert afforestation technology through the advancement of water retention technology and biotechnology.
	Production	08	Practical use of room temperature superconductors in industrial products.
2017	Life science	91	Development of technologies which dramatically improve photosynthetic ability in order to increase food production.
	Electronics	08	Practical use of non-volatile, erasable with more than 100 Gbits capacity random access semiconductor memories.

3.2. Chronological table of technology forecast (Cont'd)

Year	Field		Topic
	Materials	107	Practical use of processes for water decomposition by the sunlight.
	Production	49	Widespread use of low entropy-generating eco-factories, which give due consideration to the impact on local ecosystems throughout product life cycles, from manufacture to disposal.
	Urbanization	05	Practical use in Japan of a mid-term (5 - 10 years in advance) prediction technique for large-scale (Magnitude 8 or stronger) earthquakes based on analyses of the distribution of strains in the earth's crust and past earthquake records.
2018	Production	51	Advancements in technological development such as carbon dioxide recovery and detoxification of harmful wastes, leading to the widespread use of global environmental conservation measures throughout the world.
	Agriculture etc.	84	Practical use of a system of removing almost the entire pollution load on lakes, bays and other closed water bodies that are suffering from water quality degradation by developing environmental restoration technology that utilizes ecosystems and biological functions.
	Production	42	Widespread use of non-fossil energy sources (wind, geothermal, solar (photovoltaic/solar thermal) and waste heat) in all areas of life including household, industry and transportation.
	Health	95	Elucidation of individual aging mechanisms.
2019	Resources	63	Practical use of technology for the safe disposal of highly radioactives solid waste.
2020	Life science	28	Control of signal transduction in the carcinogenesis of cells, and widespread use of treatment methods for dysdifferentiating carcinogenic cells.
	Space	36	Capability for transmission of electrical power to earth by microwave from solar power generation plants with huge solar cell panels, constructed in space.
	Materials	44	Development of superconductive materials with a transition temperature around room temperature.
	Marine science	56	Development of technology to alleviate dangerously heavy rainfall through the application of nephology.
2021	Resources	56	Practical use of hot dry rock power-generating technologies.
	Production	55	Practical use of technologies for mass-producing hydrogen by decomposing organic substances through application of solar energy and biological systems.
	Space	38	Development of manned orbital transfer vehicle for trips to and from geostationary orbits and the moon.
2022	Environment	09	Reduction of global carbon dioxide emissions to 20% below the 1990 level.
	Electronics	66	Development of a strage system in which one atom or molecule corresponds to 1 bit.
2023	Life science	65	Elucidation of brain mechanisms for logical reasoning.
	Marine science	60	Development of technology capable of forecasting the occurrence of major earthquakes (magnitude 7 or above) several days in advance.
	Information	35	Elucidation of human creative mechanism to such an extent that allows to apply to computer science.
2024	Electronics	21	Development of an "artificial intelligence chip" capable of understanding and sharing human emotions.
	Resources	75	Practical use of superconductive energy storage systems with a capacity (1000 MWh) as large as that of pumped hydro storage.
2025	Life science	58	Development of interfaces enabling direct linkage between the computer and the brain.
	Resources	77	Practical use of power networks utilizing superconducting cables.
	Resources	58	Practical use of fast breeder reactor systems including nuclear fuel cycle.
2026	or later Information	38	Become possible for computers, using electromagnetic data, to read the information recorded inside the human brain.
	Resources	59	Development of fusion reactors.

4. Leading countries etc.

4.1 Trends in each field

Here we have converted the average topic response rate in each field for each of the five country / region options (USA, EU, Former Soviet Union and Eastern Europe, Japan, Others, Do not know) into graph format.

The USA is regarded to be the leading country in 11 of the 14 fields, and especially so in the "space," "life science," "information," "communication" and " health, medical care and welfare" fields. In the remaining three fields ("resources and energy," "urbanization and construction" and "transportation"), Japan is placed above the USA. The EU is rated quite highly in "environment" and "transportation." However, in this survey the respondents were able to give multiple responses for the "leading country etc.," so the final figures show the rate at which each of the countries or regions attracted "votes," and not a relative evaluation of their technological level. For example, even though there may be only a very slight difference between a country in the first group and a country in the second, the second group country may attract hardly any votes. There is also a difference in the volume of information each of the countries or regions publish, so it is anticipated that in cases where only limited information reaches Japan, those countries or regions will be at a disadvantage. Moreover, many of the topics themselves are considered necessary and are being tackled in Japan, and most of the technologies are at the applied stage (i.e. practical use or widespread use), so we should keep in mind that these factors will tend to push up Japanís relative percentage.

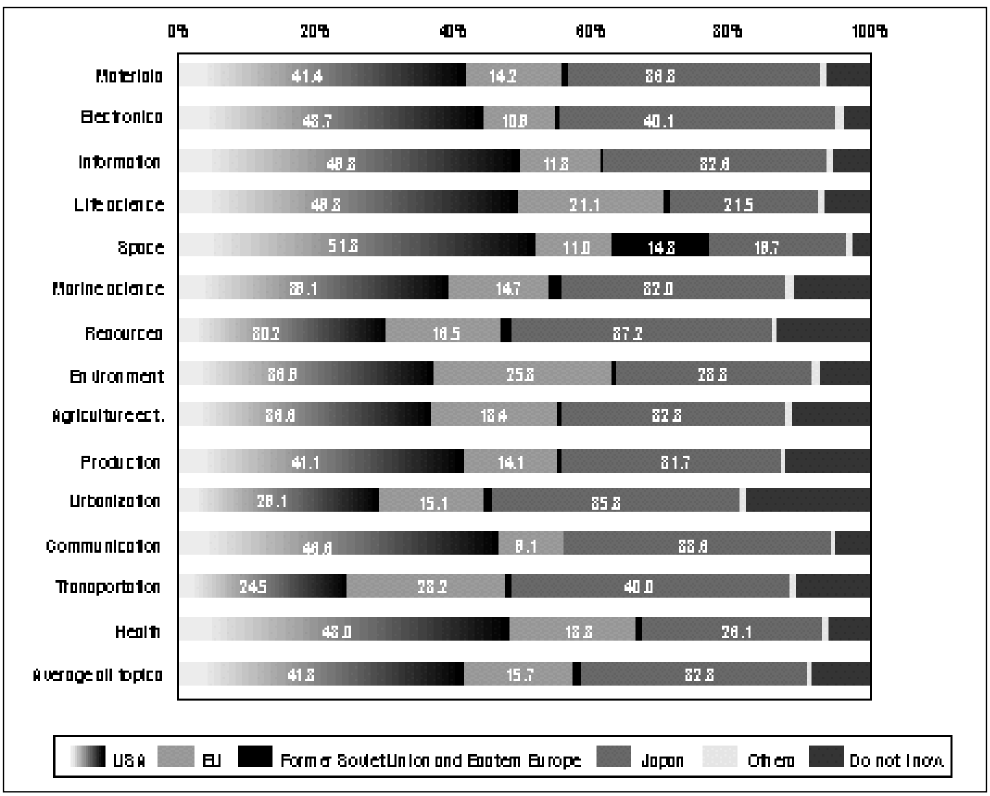


Fig. 4.1-1 Leading countries etc. by field.

5. Effective measures the government should adopt in Japan

We asked respondents to indicate whether they believe the government should adopt any measures to promote the technological topic, and if so, to choose up to three measures from among the following.

- Foster researchers, engineers and research assistants
- Enhance systems to promote personnel exchanges among the industrial, academic and government sectors and cooperation among different fields of science and technology
- Upgrade advanced R&D facilities and equipment and make them available for more widespread use
- Develop a research base comprising data bases, standard reference material, genetic resources and the like
- Increase the government's funding for research
- Adjust relevant regulations (relax / toughen / establish / abolish)
- Others

5.1 Overall trends

Figure 5.1-1 shows the average percentage value for all topics in each field. The average of all topics is quite high in "increase government research funding"

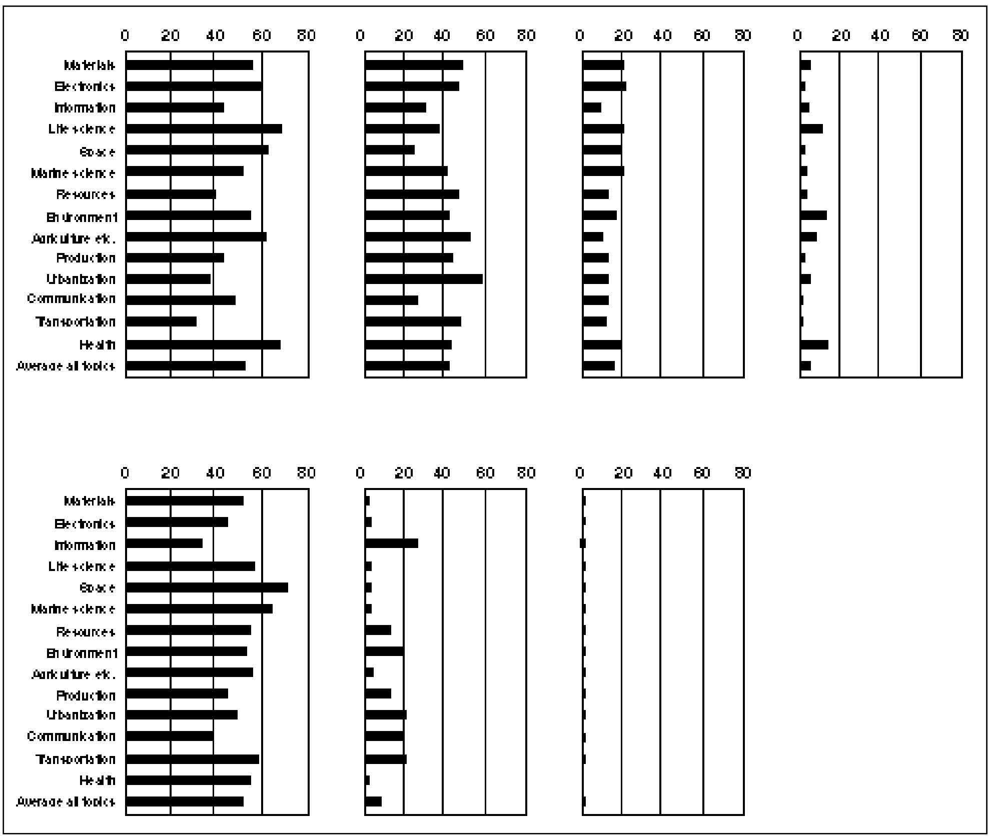


Fig. 5.1-1 Measures the government should adopt by field.

(52.5) and "foster human resources" (52.1), followed by "promote personnel exchanges among the industrial, academic and government sectors and different fields" (42.4). This shows that over many topics, respondents want the government to provide greater R&D support in both personnel and funding aspects, and play a coordinating role in personnel exchanges and cooperation.

On the other hand, it is quite low in "develop a research base" (5.3) and "adjust regulations (relax/toughen)" (10.5), indicating there were relatively few topics for which respondents believed developing a research base and adjusting (relaxing or toughening) regulations would be effective.

The figures show that in some fields expectation of government participation is indeed strong, while in others it is less so. To quantify these expectations, we totaled the percentage values of — for each topic, and plotted the field averages on a graph, shown at Figure 5.1-2. Since respondents could select up to three responses for each topic, the maximum value is 300. The aggregate value is smaller in " information" and "communication," fields with many topics with a relatively early forecasted realization time, and larger in the "health," "environment," "life science" and "agriculture etc." fields. As shown in Table 5.1-1, four of the top five topics are connected with gene technology.

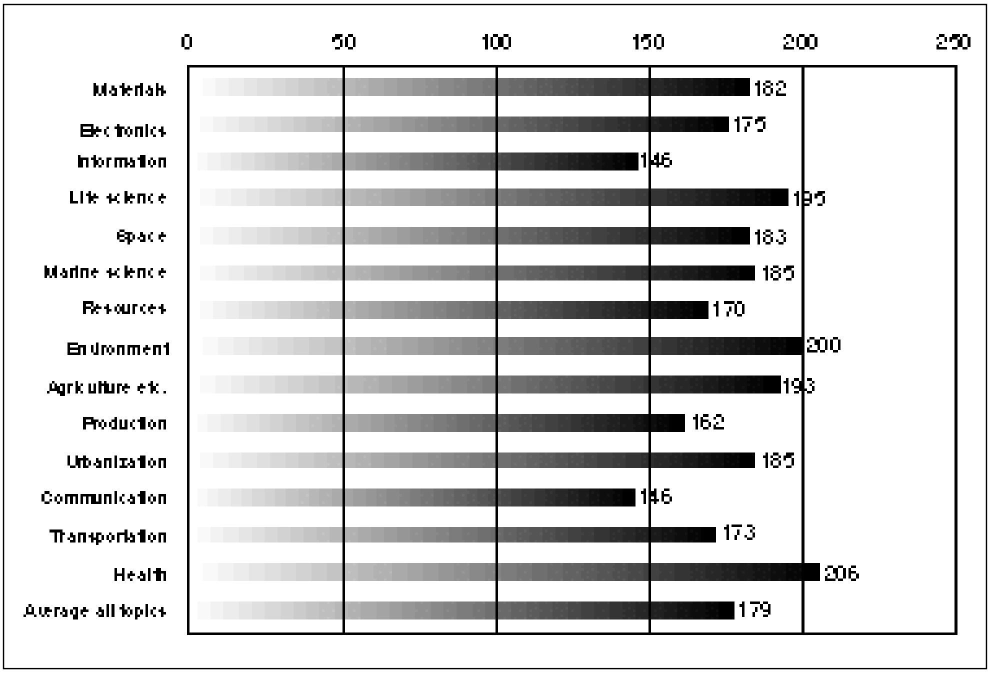


Fig. 5.1-1 Response aggregates for measures the government should adopt.

Table 5.1-1 Topics with a high response in "Measures the government should adopt."

Ranking	Field	Topic	Number of responded times	Forecasted realization time
1	Agriculture etc.	01 Elucidation of the whole DNA sequences of crops (e.g. Rice) to isolate useful genes.	2.44	2009
2	Health	51 Widespread use of gene therapy against malignant tumors.	2.39	2014
3	Agriculture etc.	02 Practical use of crop varieties having the characteristics (higher yield and more disease- and cold-resistance) improved by gene manipulation.	2.37	2004
4	Health	05 Elucidation of carcinogenic mutation mechanisms.	2.36	2013
5	Life science	01 Identification of multiple genes related to cancer, and elucidation of the relationships between those genes and carcinogenesis.	2.36	2014

6. Potential problems in Japan

In this section, we asked respondents to indicate whether they believe there are any potential problems that should be considered beforehand in relation to the realization of each of the topics, and if so, to choose up to two items from among the following.

- Adverse effect on the natural environment
- Adverse effect on safety
- Adverse effect on morals, culture or society
- Other adverse effects

6.1 Overall trends

Figure 6.1-1 shows the average percentage value for all topics in each field. The average of all topics is quite low in "adverse effect on the natural environment," "adverse effect on safety" and "adverse effect on morals, culture or society," indicating that overall the respondents have no major concerns that topic realization could produce an adverse effect.

Fields where concern about an "adverse effect on the natural environment" is relatively high are those closely linked to the natural environment, such as "environment" (47.4), "resources" (38.1) and "agriculture etc." (27.5). In contrast, concern was lowest in "information" (1.0), "health" (1.1) and "electronics" (1.6).

As for "adverse effect on safety," concern is highest in the urban-base fields of "transportation" (30.4), "urbanization" (24.7) and"information" (22.9), and lowest in the basic technology fields of "materials" (4.6) and "electronics" (5.5).

As for "adverse effect on morals, culture or society," concern is by far the highest in the "health" field (37.7), followed by "information" (27.5) and "life science" (21.9), and lowest in "transportation" (2.0), "resources" (2.7) and "marine science" (2.9).

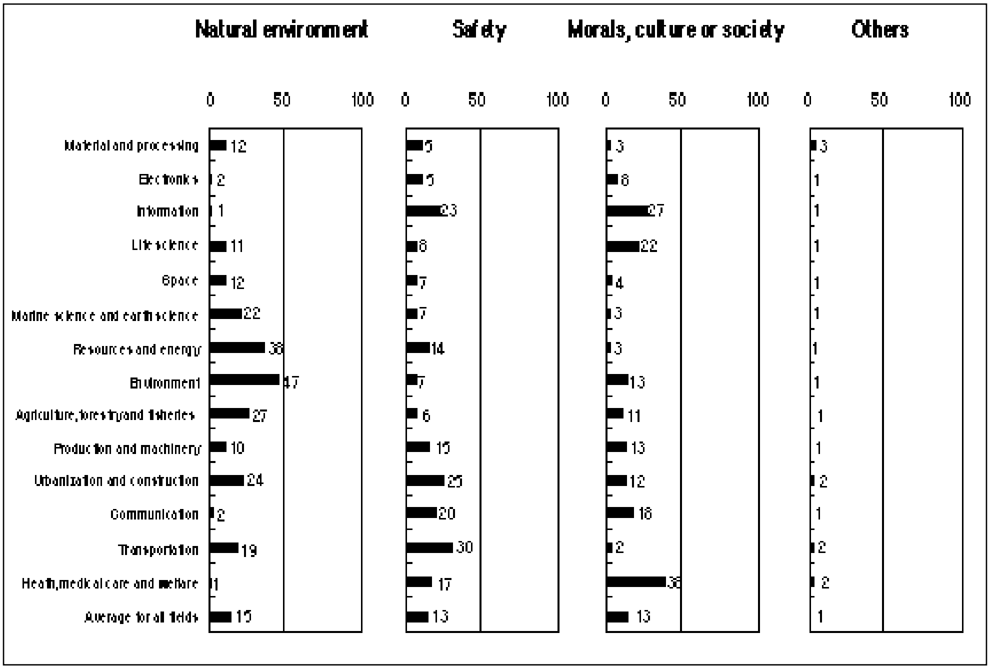


Fig. 6.1-1 Potential problems in Japan.

Table 6.1-1 Top 5 topics in "Adverse effect on the natural environment".

Ranking	Field	Topic	Natural environment	Forecasted realization time
1	Resources	01 Practical use of solution mining, a technology to recover minerals from deep underground deposits by rendering ores such as chalcopyrite and sulfides of lead and zinc into solutions and pumping them up.	84	2020
2	Environment	10 Development of storage methods of carbon dioxide at deep sea levels of more than 3,000 m below surface.	75	2014
3	Resources	20 Practical use of inducing artificial rainmarking in event of drought.	74	2014
4	Life science	40 Widespread use of worldwide environmental remediation using genetically-engineered microorganisms released into the environment.	72	2016
5	Agriculture etc.	45 Realization of the creation of varieties of fisheries-resource aquatic organisms with traits advantageous for cultivation, such as high resistance to changes in water temperature and diseases, through cell fusion, gene manipulation, etc.	72	2010

Table 6.1-2 Top 5 topics in "Adverse effect on safety".

Ranking	Field	Topic	Safety	Forecasted realization time
1	Information	66 Widespread use of electronic money to settle monetary matters.	67	2006
2	Communication	67 Widespread use of electronic commerce carried out via a network based on an electronic funds transfer system and electronic money system.	67	2006
3	Communication	66 Widespread use of on-line seal-less document preparation services for various official documents such as contract documents which are provided via a network based on security technology capable of achieving both privacy protection and verification.	66	2008
4	Information	67 Become possible to verify the counterparty to a contract concluded over a network with the use of database systems.	66	2004
5	Information	57 Full computerization of the foreign exchange, stock and other financial markets, and widespread use of fully automated rapid trading systems that do not require dealers or traders.	64	2005

Table 6.1-3 Top 5 topics in "Adverse effect on morals, culture or society".

Ranking	Field	Topic	Morals, culture or society	Forecasted realization time
1	Life science	03 Utilization of information about the gene structure of each individual patient in diagnosis and treatment.	75	2015
2	Communication	01 Practical use of a highly secure next-generation internet that allows the transmission of real-time information, leading to the implementation of internet-based telephone services and motion video broadcasts.	73	2003
3	Health	02 Practical use of a method to quantitatively assess the level of aging (biological age) in relation to chronological age.	68	2008
4	Health	76 Widespread use of a worldwide organ supply system.	68	2010
5	Information	38 Become possible for computers, using electromagnetic data, to read the information recorded inside the human brain.	67	2026

Section 3: Forecast Topic Framework

Table 1 Forecast Topic Framework for Materials and Processing Field.

Objective \ Domain	Biological	Organic and high polymer	Ceramic	Metal	Semiconductor and electronics	Composite	Other
High performance Functionality	01 02 03 04 05 06	11 12 13 14 15 16 17 18 19 20 21 22	37 38 39 40 41 42 43 44	51 52 53 54	61 62 63 64 65 66 67 68 69 70 71 72	88 89 90 91 92	
Analysis, measurement and simulation	07	23	45	55	73 74 75 76		95 96 97 98 99 100 101 102 103 104
Chemical processes	08	24 25 26 27 28 29 30 31 32	46 47 48	56 57 58	77 78 79 80 81 82 83	93 94	105 106
Global-scale problems, environment, resources and energy	09	33 34 35 36	59	84 85			107 108 109
Processing methods, devices and systems	10		49 50	60	86 87		

*** Figures appearing in the table represent topic numbers.**

Table 2 Forecast Topic Framework for Electronics Field.

Objective \ Domain	Microelectronics	Optoelectronics	Molecular, sensor and bioelectronics	Storage and display electronics
Pursuit of new scientific principles, new phenomena and new devices	01 02 03 04	31 32 33 34 35	50 51 52	66
High integration and high capacity	05 06 07	36	53	67
Miniaturization and expansion in size	08		54 55	68
High speed	09 10 11 12 13	37	56	
Super-parallel processing	38	39		
High sensitivity and high resolution	14	40	57 58 59	
High performance, high functionally, systems integration and knowledge accumulation	15 16	41 42 43	60 61 62 63 64	69 70
High efficiency, high output and low power consumption	17 18 19	44		
Large scale and wide area		45 46 47		71 72
Intelligence, flexibility, ease of use, human interface and portability	20 21 22 23 24 25	48	65	73 74
High productivity, high reliability, low price, and rationalization of design and testing	26 27 28 29 30	49		

Table 3 Forecast Topic Framework for Information Field.

Domain / Objective	Technology			Application		
	Computers and related equipment	Networks	Software and algorithms	Lifestyle, medical care, welfare and disaster prevention	Society, work, and local community	Education and entertainment
Pursuit of new principles	01	16	24			
High integration, miniaturization, high capacity, high speed, super-parallel processing, high performance, high output (including high performance) and low price	02 03 04 05 06 07 08 09 10 11 12 13	17 18	25 26 27 28 29 30 31		56 57	71
Large scale and wide area		19 20 21		46	58 59 60 61 62	72 73
High reliability and safety		22 23		47 48 49	63 64	
Intelligence and flexibility (including fuzzy technology) Ease of use (human interface)	14		32 33 34 35 36 37 38 39 40 41 42	50 51 52 53 54 55	65 66 67 68	74 75 76 77 78 79
Low environmental load (low pollution, resource conservation and energy conservation)	15				69	
High productivity			43 44 45		70	

*** Figures appearing in the table represent topic numbers.**

Table 4 Forecast Topic Framework for life Science Field.

Domain / Objective	Molecules	Cells	Tissues and Organs	Individuals	Groups
Medical care	01 02 03 04 05 06 07 08	27 28 29	47 48 49 50 51 52 53 54 55 56	67 68 69 70 71 72 73 74 75 76	
Information	09 10		57 58		
Food	11	30		77 78	91 92
Industry	12 13 14 15 16 17 18	31 32 33 34 35 36 37	59 60 61 62		
Environment and energy		38 39 40		79 80 81	
Elucidation of biological phenomena that form the basis of various technologies	19 20 21 22 23 24 25 26	41 42 43 44 45 46	63 64 65 66	82 83 84 85 86	93
Others				87 88 89 90	94

*** Figures appearing in the table represent topic numbers.**

Table 5 Forecast Topic Framework for Space Field.

Objective \ Domain	Low and intermediate orbit	Stationary orbit	Moon and its neighborhood	Planets and deep space
Probing and observation	01 02 03		39 40	43 44 45 46 47 48 49
Positioning	04 05 06 07 08 09 10 11 12 13 14 15	33 34 35		
Environmental applications	16 17 18			
Material and energy-related applications	19	36	41 42	50
Transportation	20 21 22 23 24 25	37 38		51
Technologies relating to human activities	26 27 28 29 30 31 32			

*** Figures appearing in the table represent topic numbers.**

Table 6-1 Forecast Topic Framework for Marine Science Field.

	Sea surface	Sea-land interface	Water mass	Circulation
Marine Observation, forecasting, monitoring and surveying (elucidation of phenomena, accumulation of data, and predication/forecasting)	01 02 03	04	05 06 07 08 09 10 11	12 13 14 15 16
Protection/creation of marine environment	17	18 19 20 21 22 23 24	25	26
Resources, energy and space utilization	27 28 29	30 31 32	33 34 35 36 37 38 39	40

Table 6-2 Forecast Topic Framework for Earth Science Field.

	Atmosphere			Geosphere	
	Stratosphere	Troposphere	Atmosphere-geosphere boundary	Crust	Interior of earth
Earth observation, forecasting, monitoring and surveying (elucidation of phenomena, accumulation of data, and predication/forecasting)	41 42	43 44		45 46 47 48 49 50 51	52
Protection/creation of global environment				53 54 55	
Natural disaster prevention/preparedness		56 57	58 59	60 61 62 63	
Common/other (marine/earth science)	64 65 66 67 68 69 70 71 72 73 74				

Table 7-1.1 Forecast Topic Framework for Mineral Resources Field.

Domain / Objective	Metal	Non-metal	Scarce resources	Common
Exploration, recovery and extraction	01 02 03 04		08 09	12 13 14 15 16 17
Application development / recycling			10 11	
Substitution	05	07		
Environmental protection and safety	06			18 19

Table 7-1.2 Forecast Topic Framework for Water Resources Field.

Domain / Objective	Rainfall and groundwater	Rivers, lakes	Municipal water supply and sewage/drainage services	Seawater	Common
Water resource development technology	20 21 22	23 24	25 26		27 28 29
Flood prevention / preparedness technology	30 31	32	33	34	
Water quality improvement technology		35	36 37	38	39

*** Figures appearing in the table represent topic numbers.**

Table 7-2 Forecast Topic Framework for Energy Field.

Domain	Primary energy		Second energy				Energy-related
Objective	Oil, coal and natural gas	Solar, wind power, ocean energy, biomass and geotherm	Nuclear	Processed energy sources (hydrogen, methanol, etc.)	Electricity	Heat and mechanical energy	systems (energy conservation, combined-cycle systems, etc.)
Exploration, recovery and extraction	40 41				69		
Production	42	45 46 47 48 49 50 51 52	58 59 60	64 65	70 71 72 73 74		86
Storage and transportation		53			75 76 77 78 79		
Utilization	43	54 55 56	61	66 67 68	80 81 82 83	84	87 88
Environmental measures / safety (recovery and disposal)	44	57	62 63			85	

*** Figures appearing in the table represent topic numbers.**

Table 8 Forecast Topic Framework for Environment Field.

Domain / Objective	Global environment: Depletion of ozone layer	Global warming	Acid rain	Marine pollution	Diminishment of tropical rain forests	Desertification	Common
Elucidation, prediction and observation of phenomena	01 02	05 06	12	14			22
Elucidation, prediction and observation of impacts	03	07 08	13	15	17 18	20	
Prevention, control and management	04	09 10 11		16	19	21	23

*** Figures appearing in the table represent topic numbers.**

Domain / Objective	Local environment: Air quality	Water quality	Noise/vibration	Waste	Nature/ecosystems	Cross-sectional
Elucidation, prediction and observation of phenomena		25				35
Elucidation, prediction and observation of impacts						36
Prevention, control and management	24	26 27 28	29	30 31 32 33	34	37 38 39

*** Figures appearing in the table represent topic numbers.**

Table 9 Forecast Topic Framework for Agriculture, Forestry and Fisheries Field.

Domain / Objective	Agriculture: Crop production	Agriculture: Animal husbandry/grazing	Forests/forestry industry	Fisheries industry	Other new industries based on living organisms	Common
Breeding and development of biological functions	01 02 03 04 05 06	22 23 24 25 26	36	45	57 58 59 60 61 62 63 64 65	69 70 71
Cultivation and feeding management	07 08 09 10 11 12 13 14 15	27 28 29 30 31 32 33	37 38	46 47 48 49 50 51 52	66	72 73
Storage, distribution and processing	16 17 18 19 20	34	39 40 41		67 68	74 75 76 77
Management and assessment of environment and biological resources	21	35	42 43 44	53 54 55 56		78 79 80 81 82 83 84

*** Figures appearing in the table represent topic numbers.**

Table 10 Forecast Topic Framework for Production and Machinery Field.

Domain / Relationship	Common foundation	Manufacturing systems (production)	Administration/distribution system (distribution)	Social/global systems (consumption)
Tools (implements and machinery)	01 02 03 04 05 06 07	08 09 10 11 12 13 14 15		16
Information (electronics)	17 18 19	20 21 22 23 24 25 26	27 28 29 30 31 32 33 34	35 36 37 38 39 40
Energy	41 42 43	44 45		46
Environment	47	48 49	50 51	
Living organisms	52 53 54 55 56 57 58 59 60	61 62 63 64		
Human beings	65		64	67 68 69 70 71
		66		

*** Topic 64 appears in two cells as two domain-relationship combinations apply to it.**

*** Figures appearing in the table represent topic numbers.**

Table 11 Forecast Topic Framework for Urbanization and Construction Field.

Domain / Objective	City functions (overall hardware/software infrastructure of cities)	Basic facilities (lifeline facilities etc. of cities in general)	Civil engineering (individual civil engineering structures)	Architecture (individual architectural structures)
Ensuring safety	01 02 03 04 05 06 07 08 09	10 11	12	13 14 15
				16
Coexistence with nature / environmental conservation	17 18 19	20 21 22 23 24	25 26 27	
				28
Resource and energy conservation / recycling	29	30 31	32 33	34 35 36 37
			38	
Response to increasingly diverse and individual lifestyles	39			40 41 42 43
Promotion of welfare / response to aging society		44	45	46
Improvement of productivity	47		48 49 50 51	52 53 54 55 56 57
			58	
Advanced use of national land and cities	59 60	61 62 63 64	65	
			66	
Effective use of new frontier spaces	67 68	69	70	71 72 73 74

*** Figures appearing in the table represent topic numbers.**

Table 12 Forecast Topic Framework for Communication Field.

Objective \ Domain	Transmission technology	Switching technology	Satellite and mobile communication technology	Broadcasting, multimedia communication and intelligent system technology	Networking technology	Security technology	Common element technologies
Pursuit of human touch, culture and comfort and enhancement of measures to cope with aging of population			14	27 28 29 30 31 32 33 34 35 36 37			71
Pursuit of personalized / privatized information and convenience	01 02		15 16 17 18 19	38 39 40 41 42 43	58 59 60	66 67	72 73
Pursuit of greater efficiency and cost cutting	03 04 05 06 07 08	10 11 12 13	20 21 22 23	44 45 46 47 48 49 50			74
Environmental protection, recycling, improvement of social environment and problem solving			24 25		61		75 76 77
Provision of sense of security and reliability (disaster preparedness, safety, privacy protection, etc.)			26		62 63 64 65	68 69 70	78
Greater user-friendliness (improved ease of use and interaction)	09			51 52 53 54 55 56 57			

Table 13 Forecast Topic Framework for Transportation Field.

Objective \ Domain	Rail and track transportation systems	Road transportation systems	Water and underwater transportation systems	Air transportation systems	Other new transportation systems
Transportation services that are comfortable and convenient to use (comfort, human touch, culture, convenience, elements of play and response to aging population)	01	10 11 12 13 14	33	46 47	57 58 59
Provision of efficient transportation services (high speed, reliability, economy, and automation / labor saving)	02 03 04 05	15 16 17 18	34 35 36 37 38 39 40 41	48 49 50 51 52	60
Provision of safe transportation services (safety and reliability / maintainability)	06 07	19 20 21 22 23 24 25	42 43 44	53 54	
Provision of environmentally-friendly transportation services (environmental protection and resource / energy conservation)	08 09	26 27 28 29 30 31 32	45	55 56	

Table 14 Forecast Topic Framework for Health, Medical Care and Welfare Field.

Domain / Objective	Infectious diseases, immune disorders, and metabolic/ endocrine diseases	Neoplasms	Neurological, mental and muscular diseases	Circulatory, renal and respiratory diseases	Digestive system diseases	Birth trauma and newborn disorders	Injuries (including accidents)	Hereditary diseases	General/ common
Health promotion			01						02
Elucidation of disease development mechanisms	03 04	05 06	07	08 09 10					
Improved standard of prevention methods	11 12 13		14 15		16	17 18 19			20
Improved standard of testing and diagnostic methods	21	22 23 24	27	28 29	30				31 32 33 34
Improved standard of treatment methods	35 36 37 38 39 40 41 42 43	44 45 46 47 48 49 50 51	52 53 54 55 56 57 58	59 60 61 62 63 64 65	66 67 68 69		70 71 72	73 74	75 76 77 78 79
Improved standard of rehabilitation / assistance			80 81 82 83 84				85 86		
Integration (systems approach)				87					88 89 90 91 92
Basic (elucidation of functions and nature of living bodies, etc.)			93 94 95						96 97 98

*** Figures appearing in the table represent topic numbers.**

Priority Setting for Science and Technology in the Public and Private Sectors in Canada

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Introduction

As the world heads irreversibly towards economic globalization, competitiveness of knowledge-based economies is becoming increasingly dependent on the development of leading-edge technologies and their rapid application by an economy's innovation system. The challenges facing individual economies are, then, to not only increase knowledge-intensive economic activities and to become more efficient in gathering, diffusing and utilizing knowledge in the innovation system, but also to develop methods to set S&T directions and investment priorities to maximize the impact of their activities.

Since Canada has a small, open and interdependent economy, composed of a majority of small- and medium-sized enterprises (SMEs), maintaining Canada's competitive position in this global context has raised concerns. These concerns are all the more acute since increasing global competition among the knowledge-based economies is occurring in a climate of reduced government spending in all areas, including S&T. Increasingly, government investment needs to be focused and targeted to make the most effective use of limited resources.

This paper will present the recent Canadian experience in science and technology priority setting and strategy development which was undertaken in response to the need for fiscal austerity in an environment of increasing global competition. The first part provides an overview of the R&D and S&T scenes in Canada. Then it presents recent reviews of the federal government's S&T activities and its new S&T strategy and the National Research Council's experiences in priority setting for science and technology. Finally, the paper briefly examines strategies for priority setting for science and technology in concert with the private sector.

1. The R&D and S&T Scenes in Canada

Overall research and development expenditures in Canada represent about 1.5 percent of GDP. Expenditures have grown steadily from 1981 to 1995, from about $4 Billion in 1981 to about $12 Billion in 1995. The Gross expenditures on R&D as a percentage of GDP have grown from 1.2% to 1.5% over this period (see annex 1). Of this total expenditure, the share of the Federal government decreased slightly since 1984, while that of the private sector has increased. In the meantime, the higher education sector has maintained its funding level while foreign investment in R&D in Canada has increased. In 1995, for example, the private sector carried out 60% of all the R&D done in Canada and funded 46.7%, while the public sector, which includes universities, did 38.7% and funded 40.2% (see annex 2). Foreign firms and agencies contributed about 11% of the R&D funding in Canada in 1995.

Although Canada carries out R&D in a large number of sectors, we have focused significant resources in the areas of telecommunications ($ 2 145 M), manufacturing ($ 920 M), aerospace ($ 765 M) and pharmaceuticals ($ 580 M) (see annex 3). While these numbers are for industrial expenditures only, there is a similar trend in the public sector as well. It is worth noting that these priorities mirror those identified in other countries, such as the UK, Japan, Germany and Australia which have carried out technology foresight studies (see annex 4).

2. The Recent Federal Government S&T Review

In 1994, the Canadian federal government launched a major review of its expenditures and programs related to science and technology. This S&T Review was part of a government-wide Program Review aimed at getting government spending under control, reducing duplication and focusing activities more closely to the strategic priorities of the future. As part of the S&T review, seventeen industrial sectors were examined, covering a broad range of industries from resource to high-technology manufacturing and services. This exercise provided the basis for understanding the relationships between Canada's resource, manufacturing and service industries and enabled the identification of trends and opportunities in key sectors of the economy where federal S&T could have a positive impact.

Through a broad consultation process, which included Canada's industries, the federal government established its strategic priorities for technological investment. It led to the identification of two new priority areas for federal S&T support: information and telecommunication technologies (IT&T) and advanced manufacturing technologies (AMT). As well, the commitment to key technologies, such as biotechnology and environmental technologies, was renewed. These technologies fall into the category of "enabling technologies", which are the technological base for new products and processes upon which many industries depend for competing in global markets. It is also acknowledged that stimulating the development of these enabling technologies will leverage subsequent applied

R&D in a number of sectors of the economy, providing important technological spillovers and contributing to making those sectors more efficient and productive. As such, these areas for federal S&T investment were selected on the basis of their potential to be key generators of future wealth in Canada, their correspondence with competencies and resources of the government's S&T agencies and their potential to form strong links to Canadian industry.

In March 1996, after unprecedented consultations, the Federal government issued a new strategy entitled, *Science and Technology for the New Century*. This strategy outlines a series of governance mechanisms, operating principles and priorities that will guide Federal S&T into the next century. Recognizing the role of knowledge and technology in economic growth, the Federal science and technology strategy is based on a set of national goals to which our S&T resources should be directed. These goals are:

1. sustainable job creation and economic growth;
2. improved quality of life; and,
3. advancement of knowledge.

To further the management of the Federal government S&T effort in a more comprehensive and coordinated way, the S&T strategy created new institutions and mechanisms to improve advice, governance, decision making and coordination. One of these new mechanisms is the recently established Advisory Council on Science and Technology (ACST), which reports directly to the Prime Minister and provides strategic advice on a range of S&T issues to the Cabinet-level Economic Development Policy Committee.

The strategy also defines seven operating principles to guide government's departments and agencies in performing and investing in S&T into the next century. These operating principles are:

- increasing the effectiveness of federally supported research;
- capturing the benefits of partnership;
- emphasizing preventive approaches and sustainable development;
- increasing industry competitiveness by positioning Canada within emerging international regulatory, standards and intellectual property regimes;
- building information networks - the infrastructure of the knowledge-based economy;
- extending science and technology linkages internationally; and,
- promoting a stronger science culture.

Following closely upon this strategy were Action Plans for each Federal area of S&T activity to put these goals and principles into action. A central theme of these Plans is a new managed approach to coordination and cooperation among the various Federal players in S&T. The creation of the "Industry Portfolio" - a grouping of 11 Federal departments and agencies which report through the Minister of Industry, was a commitment to this new managed approach.

The Industry Portfolio includes five Federal R&D funding and performing organizations (including NRC), three regional development programs, a financial organization, a Federal standards body and the national statistics agency. Together, these 11 organizations oversee a combined annual investment in S&T of more than $2 billion, which represents 41% of total federal S&T spending.

The Industry Portfolio is creating a new vision and a new strategic approach based on coordinating the distinctive capabilities of its department and agencies. This approach is founded on a common belief in the importance of entrepreneurship, cooperation, and partnership that will foster collaboration and promote synergy. It is also founded on the role of government as a catalyst within the Canadian system of innovation.

3. Determining priorities and aligning portfolio partners programs

Although there are a growing number of initiatives designed to implement the S&T strategy, notably with regard to the priority areas for investment, the development of partnerships and the alignment of portfolio partners programs, the following are some key examples.

- *Research Partnership Program.* This is a joint initiative of the National Research Council and a university granting council, called the Natural Sciences and Engineering Research Council. This program is designed to create strong three-way linkages and synergy among NRC's research institutes, university researchers and the private sector by leveraging complementary R&D capability.
- *The Federal Networks of Centres of Excellence.* The Federal Networks of Centres of Excellence is a unique initiative designed to foster cooperation between research in public institutions and in private enterprises. These networks undertake multidisciplinary targeted research designed to accelerate the transfer of technology to industry through government-university-industry partnerships, to develop Canada's economy and to improve the quality of life of Canadians.
- *Technology Partnership Canada (TPC).* TPC is designed to share the risks and rewards of high technology investments with the private sector. The aim of the TPC is to increase investment in globally competitive industries such as environmental technologies, enabling technologies (biotechnology, advanced manufacturing, advanced materials, information technology) and aerospace and defense industries.
- *Technology Incubators.* A biotechnology incubator facility has been built at NRC's site in Montreal, funded jointly by the NRC, the federal regional development agency in Quebec and a private developer. Another is being built by NRC at its campus in Ottawa for Information Technology industries. Technology incubators associated with NRC institutes in other parts of Canada are also being developed or planned to help foster the growth of spin-offs and SMEs.
- *Community Innovation.* In recognition of the fact that innovation is driven by regional and community-based systems, NRC is contributing to strengthening geographic technology clusters by working in concert with regional and community initiatives. To create a more integrated innovation system and to share knowledge and information, NRC is establishing partnerships and networks with all elements of the regional innovation system.
- *The Canadian Foundation for Innovation (CFI).* The CFI has been established to provide financial support for modernizing research facilities and equipment at Canadian post-secondary educational institutions and research hospitals in the areas of science, engineering, health and the

environment. The $800 M set aside will provide $180 million annually for research infrastructure during the next five years with matching contributions from other levels of government, industry and private sources.

- *Youth Initiatives:* The Federal Government has identified the availability of highly qualified personnel as a priority for S&T. A number of new initiatives have been developed to help address the shortages of quality jobs for youth including the Technology Internship Program managed by NRC through IRAP. Under this program, SMEs receive assistance to hire young graduates in science or related fields to work on technology projects. In 1996-97, IRAP facilitated the hiring of over 500 young people to work on technology related projects in a Canadian firm.
- *Performance Frameworks.* The National Research Council has developed a performance framework to regularly assess the continued relevance, success and performance of its programs and operations in the context of its vision. NRC's Performance Framework identifies objectives, activities, outputs, reach and immediate and longer term impacts and describes the linkages between them. This approach focuses management attention on three key performance areas including, resources, reach and results (immediate and long-term impacts). The framework is described in annex 5. A similar exercise is underway within the Industry Portfolio.

4. Priority Setting at the National Research Council of Canada

The Federal Government's S&T review concluded that if Canada is to optimize its effectiveness in meeting the challenges of market globalization, it had to ensure that all of its resources support the government's economic agenda, including the government's S&T assets. This led to a major examination of the modus operandi of every element of the Canadian innovation system within the federal government, including the NRC.

The budget cutbacks and the new strategy of the government challenged NRC (the most important performer of R&D in Canada) to concentrate more intensely on what it does best and where it can have most impact. As a result, NRC, in consultation with its partners and clients, terminated some programs and refocused others.

NRC began by developing a new vision in accordance with the Canadian government S&T strategy for the new century: *As Canada's foremost R&D agency NRC will be a leader in the development of an innovative knowledge-based economy through the application of science and technology*. NRC pursues this vision, by: providing strategic advice and national leadership to integrate key players in Canada's system of innovation; collaborating with industrial, university and government partners to develop and exploit key technologies; taking a more aggressive entrepreneurial approach to ensure the transfer of knowledge and technological achievements; and advancing the frontiers of science and technology through world-class research.

NRC has realigned its research programs to focus its efforts on three industry sectors, three technology clusters, and transformational sciences (nanoscale materials and processes and supramolecular chemistry and biology) and measurement standards. The industry sector approach covers R&D activities in the construction, aerospace and marine sectors and includes the provision of important facilities and other infrastructure required by those industries. In addition, NRC provides infrastructure support in astronomy to the Canadian scientific community. The technology clusters cover R&D activities and facilities in the areas of biotechnology, information and telecommunication technologies, and advanced manufacturing technologies. NRC also conducts standards research in the areas of mechanical, physical and chemical metrology and provides measurement standards services to Canadian industry. These are fields where NRC already makes considerable contributions. They are also areas that are critical to a knowledge-based economy and to the creation of high-quality jobs in the future.

The industry sectors and technology clusters approach enable NRC to build on its strengths and develop programs in technology areas relevant to Canadian industry, reinforce the critical importance of multidisciplinary efforts and synergy within NRC's research program. However, NRC also benefits from linkages of these research programs with other important elements of its diverse activities, namely, the Industrial Research Assistance Program (IRAP), the Canadian Technology Network (CTN) and the Canada Institute for Scientific and Technical Information (CISTI).

IRAP is built on two fundamental and complementary concepts, namely networking and technology transfer. IRAP has been faithful to those concepts for 50 years as they have proven to be instrumental to IRAP's success. Networking, for example, has allowed IRAP to respond very effectively to the needs and diversity of client firms. Technology transfer, on the other hand, has allowed firms to build on existing knowledge rather than re-invent the wheel. It is a powerful process which shortens R&D time, lowers the innovation costs and risks, and prevents firms from isolating themselves in their own limited technological environment.

IRAP offers a team of almost two hundred forty-five (245) professional Industrial Technology Advisors (ITAs), composed of staff from NRC and some one hundred other organizations (Universities, Federal government organizations, Provincial research organizations etc.) located in every corner of the country. IRAP can also provide support funding for certain approved projects with eligible clients.

The Government directed that a Canadian Technology Network (CTN) be established, using IRAP and its cross-Canada network of about 245 ITAs. The decision to establish the CTN was based on the recognition that more was needed than IRAP currently provided to help firms to adapt to rapid and complex technological change. Firms needed quick access to all of the technology and related business expertise that was currently or potentially available from many other organizations.

CTN is a distributed network of expertise and information, which is helping to improve the competitive position of technology-intensive SMEs. CTN optimizes the delivery of technology and related business services to industry by linking over 500 member technology service organizations for easy access to SMEs. CTN has also been linked to Singapore's Technology Network and it is proposed to connect CTN to other APEC members as well.

Finally, the Canada Institute for Scientific and Technical Information (CISTI) is recognized as having North America's leading collection of medical, scientific, and technical information. CISTI's continuing leadership in electronic information systems led to the creation of an electronic document delivery service (IntelliDoc). This highly integrated system processes 1,500 orders daily from CISTI clients in Canada and around the world.

Separately, these elements of NRC make important contributions to the innovation system in Canada. Together, they are a powerful S&T instrument that can be brought to bear to the benefit of Canadian industry.

5. Priority Setting for S&T in the Private Sector

With a country as diverse and widespread as Canada, talking about priority setting for S&T in the private sector is a daunting task. Indeed, the nature of Canadian industry, that is the presence of a large number of multinationals, is such that decisions on S&T are often taken in other countries. Also, as was mentioned earlier, Canada has a large number of small and medium-sized firms and research and development in these firms is minimal and priority setting for S&T is related to very short-term business goals.

However, the Federal Government and the National Research Council have established a number of mechanisms to identify, in concert with the private sector, national priorities and strategies for S&T. As a member of the Industry Portfolio, NRC has been involved in a number of initiatives and pilot projects related to S&T strategy development. These include the following:

- assisting industrial sector planning through the development of a technology road maps, as for example for the aerospace industry*;
- supporting regional industrial innovation and economic growth by organizing regional innovation forum roundtables to discuss a variety of innovation issues ranging from technology trends to barriers to innovation;
- diffusing information and knowledge by gathering, assessing and disseminating science and technology information and intelligence; and
- research direction setting in specific fields through technology forecasting.

NRC's IRAP also plays an important role in priority setting for S&T in the private sector. Through advice to the SMEs, IRAP's network of Industrial Technology Advisors help identify the critical technologies and research needed to help the SME increase its competitiveness. IRAP will then assist the SME in either carrying out its own research and technology development or in finding the best source of technology in Canada and sometimes internationally.

NRC also continues to utilize broad-based consultations through its Council (board of governors), various advisory boards, and more recently with its portfolio partners and regional innovation clusters to generate its own S&T strategies and to support the development of S&T strategies of the government in general.

Conclusion

In summary, Canada has set out a series of operating principles to guide its Federal S&T activities. The new strategy reflects the need to create a system of innovation and to look at the issue in a very broad way. We are looking to enhance our ability to disseminate and use knowledge as well as create it.

These guiding principles should hold up well as we move into the next century.

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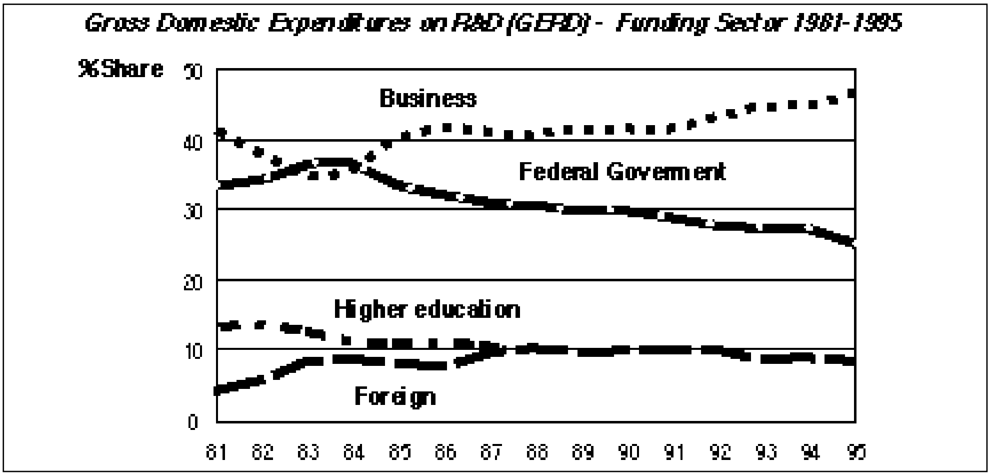
* Six industry-led technology roadmaps to identify the new technologies required by an industry to meet its future market demands are currently under development: aircraft design, manufacturing, repair and overhaul; computer equipment; forestry operations; freight transportation services; and, automotive.

Annexes

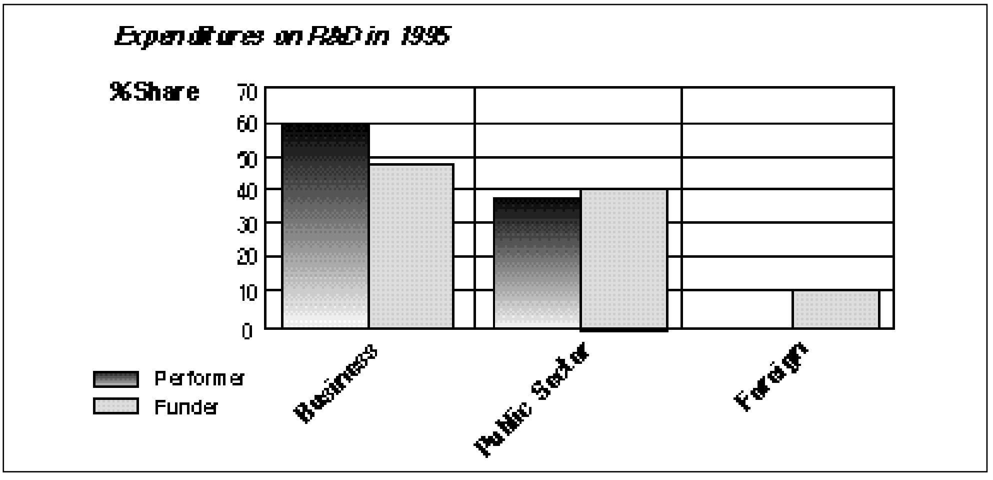
Annex 1 - Canada's R&D Effort

Gross Domestic Expenditures on R&D (GERD) - Funding Sector 1981-1995



Annex 2 - R&D Spending in Canada ($11.8 Billion/Year; 1.5% of GDP)

Expenditures on R&D in 1995



Annex 3 - Industrial R&D Expenditures on R&D in 1995

Key Sectors:	($M - estimated)
Telecommunications	2,145
General Manufacturing	920
Aerospace	765
Pharmaceuticals	580
Utilities	245
Mining/Petroleum	240

Based on Statistics Canada data,1995

Annex 4 - Comparison of Priorities of Three International Foresight Studies

UK Generic S&T Priorities	*Japan-Germany Foresight Survey Areas*	*Australia - Key forces*
Harnessing future communications and computing technology	Microelectronics and information society	Information and communications technology
A cleaner world	Prospects for a cleaner environment	Environment
Processes and products from genes to new organisms	Life sciences and the future of the health system	Genetics and biotechnology
Social shaping and impact of new technology		
Getting it right: precision and control in management		
New materials, synthesis and processing	Materials and future processes	
		Globalization

Annex 5

NRC's Corporate Performance Framework

Vision: As Canada's foremost R&D agency, NRC will be a leader in the development of an innovative knowledge-based economy through science and technology.

We will realize this vision by:

- being dedicated to excellence in advancing the frontiers of scientific and technological knowledge in areas relevant to Canada;
- carrying out focused research, in collaboration with industrial, university and government partners, to develop and exploit key technologies;
- providing strategic advice and national leadership to integrate key players in Canada's system of innovation;
- taking a more aggressive, entrepreneurial approach to ensure the transfer of our knowledge and technological achievements to Canadian-based firms

Resources		**Reach**	**Results**	
Activities	**Outputs**		**Immediate impacts**	**Long term impacts**
- Innovation & application of technology	- Projects - Products/ processes/ technologies - Advice/ assistance	*Primary Target* - Canadian industry *Collaborators/ intermediaries* - Provinces, Municipalities	- Create technology opportunities for firms - Commitment to excellence in critical areas - Support for innovation, trade & regulatory systems	- Increased competitiveness of Canadian firms - Increased investments in R&D in Canada - Leadership in the national innovation system
- Development of knowledge	- Publications/ reports - Financial contributions	- OGDs - Service sector - Universities - Research organizations	- Client focus - Employee commitment - Aligned support & management systems - Entrepreneurship	- Improved trade climate for Canadian industry - Dynamic, entrepreneurial organization
- Innovation system support - Management	- Communications - Core competencies - Management tools & systems	- Consortia		

Annex 5 (Cont'd)

Resources		Reach	Results	
Activities	**Outputs**		**Immediate impacts**	**Long term impacts**
Performance Indicators				
- Identification of key technologies, critical areas - Investments in key technologies, critical areas - Analysis of key firms by economic sector		- Clients & partners - Collaborations with key research organizations - Networks / alliances in national innovation system - Networks in regions / communities	- Innovations in client firms, new firms - Income / in-kind contribution - Participation in S&T Fora - Diffusion of STI products & services - Participation in key trade & regulatory initiatives - Adoption / use of codes & measurements - Performance against service standards	- Investments by clients & partners - Economic performance of clients & partners - Acceptability of Canadian products & services - Client feedback - Employee feedback

Application of Technology Foresight to the Formulation of S&T Policies: The Korean Experience

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1. Introduction

In the turnaround of the century, it is pointed out that Korea should renew the role of science and technology. In the process of industrialization over last three decades, the main thrust of economic development was lower wages, higher rate of savings, protection of domestic industries. However, comparative advantage depending on those factors is no more effective as idle resource are no more available and the economy is widely open to the rest of the world. Economic environment is rapidly changing as globalization prevails, and therefore needs for changing public policies are increasing for a successful transition to knowledge-based economy. It is implied that Korea should look for other sources for the competing edge, particularly focusing on S&T activities or knowledge-creating activities; that is, innovation-based strategies for development is needed.[1]

As investment in science and technology is continuously increasing to cope with rapidly changing S&T environment, technology foresight (TF) activities are required in a rational way, including priority setting, R&D evaluation and control, etc. The TF activity in Korea is not historically long-rooted, but it is recently observed that various R&D organizations carry out actively technology foresight.

The purpose of this study is to draw some lessons, reviewing TF activities in Korea. TF activities in Korea are undertaken mostly by the government sector. A major step to TF activities was the first Korean Delphi, which has had a substantial stimulation to both public and private sectors.

In the following section, definitions of technology foresight will be made. Needs and purposes of technology foresight will be also discussed. In the section 3, current activities and characteristics of technology foresight in Korea are discussed and summarized, focusing on the government sector, in line with S&T policy making. In the section 4, concluding remarks will be made.

2. Needs and Purposes of Technology Foresight

Nowadays, S&T issues become more global and complex under conditions of increasing uncertainty and risk. There is an increasing need for effective decision making, action and results. Today many believe it is possible to shape the future, rather than simply prepare for a future, which is a linear extrapolation of the present. Thus, it is required increasingly that the policy-maker and / or decision-maker should look into the longer-term future of environments surrounding science and technology, in a scientific way, where technology foresight comes into a focus.

In definitions, *technology foresight* is referred to as identifying present S&T priorities in the light of hypothetical projections of future economic and societal developments. Meanwhile, *technology forecasting* is referred to as probabilistic predictions of future technological development, and *technology assessment* as anticipating future societal impacts of known new existing technologies. However, technology foresight can be used in a broad sense for such future-oriented activity.

In general, foresight is undertaken to gain better understanding of the future environment and magnitude of the changes needed. Thus, the anticipation enables the decision-maker to move into the future in a purposeful fashion in contrast to belated reaction. In any case, the decision-maker cannot avoid making decision which will be proved good or bad upon realization of the future event. If the foresight can assist the decision-maker to obtain a more accurate picture of the future and in consequence improve his / her decision-making, the effort devoted to the foresight will be justified. This only justifies why to forecast.

It can be said therefore that the fundamental of the foresight activity is in assessment of threats and opportunities, in a systematic way, leading to strategic formulation and planning to meet the needs of the future. In summary, Jantsch pointed out that the foresight could assist decision-making in the following ways [4];

(1) Wide ranging surveillance of the total environment to identify developments both within and outside the sphere of activities which would influence the economy's future.

(2) Provision of well-refined information about the possibility of a major threat and opportunity; in some cases, an early warning signal.

(3) Estimating the time scale for important events in relation to the decision-making and planning horizons; an indication of the urgency of action.

(4) Major reorientation of S&T policy to address situations which may pose a threat and opportunities by; (a) redefinition of economic competitiveness in light of new technological competition, (b) modification of economic strategy as well as R&D strategy.

(5) Improving operational decision-making, particularly in relation to; by priority setting, (a) resources allocation between technologies, (b) R&D project selection from the R&D portfolios, and (c) human resources development.

Thus, the foresight could provide rich decision information for S&T policy formulation of both the private and the public. It is noted therefore that the foresight should not be simply outcomes of curiosity of scientists and technologists. It must be a well-controlled exercise taking account of related factors.

3. S&T Policy-Making and TF Activities in Korea

3.1. Evolution of TF Activities

Technology foresight/forecasting is relatively new concept in Korea. Technology foresight activities are undertaken in various ways in Korea, particularly at the government level. As R&D funds have been increased rapidly, a certain framework of resource allocation is necessary, including priority-setting, selection and evaluation mechanisms.

In Korea, many ministries or agencies perform its individual functions related to science, technology and innovation. The Ministry of Science and Technology (MOST) serves as the "lead agency," specializing in common, interdisciplinary and strategic areas, and assumes responsibility for overall coordination of all other ministries and agencies. For last three decades, MOST had been responsible for leading S&T activities in both the public and the private sectors. But as the society is more diversified in time and importance of science and technology is increased in wide-ranging socio-economic activities, S&T responsibilities and resources have been rendered to other ministries. Although the role of MOST is defined to carry out its own S&T operations and policies, while to coordinate R&D programs, it is difficult for the MOST to coordinate the policies and activities of other ministries and agencies. It is mainly because the system is lack of workable institutional mechanisms and its relatively weak position. Major ministries responsible for S&T activities are the MOST, Ministry of Trade, Industry and Energy (MOTIE), Ministry of Information and Communications (MIC), and Ministry of Education (MOEd), among others, particularly in response to changing national needs.

According to such evolution of the government structure and changes in policy-making mechanisms, there had been established many agencies for its own R&D management, including technology foresight, planning, evaluation and control, etc. As shown in Table 1, eight ministries are now engaged in R&D activities and have their own agencies for R&D management. Those agencies are responsible for technology foresight, planning, evaluation and resource allocation, etc. However, most of them started their operation in the beginning of 1990s, so that their TF activities are still focusing on developing methodologies and applications. It is notable under such situation that MOST with an accumulation of three-decade experiences in R&D management provided a framework for R&D management, particularly technology foresight activities.

3.2. MOST

One of the successful models of technology foresight was made when the Ministry of Science and Technology (MOST) delivered, in 1992, a national R&D program, called the HAN projects. The purpose of the HAN projects was to increase competitiveness of domestic industries by increasing indigenous capability of science and technology. It was the first attempt in a systematic way, calling for inter-ministerial collaboration in the S&T planning. It was pointed out that the

Table 1 R&D Management Agencies of the Government Sector.

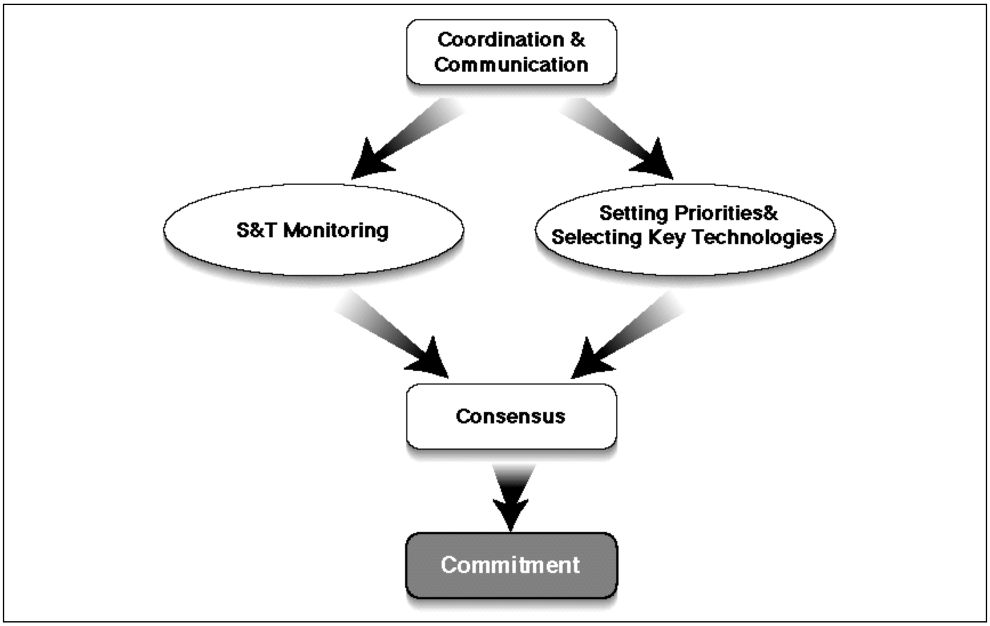
Ministry of	R&D Management Agency	Area	Start year of R&D programs
Science and Technology (MOST)	Science and Technology Policy Institute (STEPI / KIST)	Various areas	1982
	Korea Science and Engineering Foundation (KOSEF)	Target-oriented basic research	1978
Trade, Industry and Energy (MOTIE)	Industrial Technology Policy Institute (ITEP / KITECH)	Industrial technologies	1987
	R&D Management Center for Energy and Resources (RACER)	Alternative energy	1988
Information and Communications (MIC)	Institute of Information Technology Assessment (IITA / ETRI)	Information and communications	1991
Construction and Transportation (MOCT)	Korea Institute of Construction Technology (KICT)	Construction and civil engineering	1995
Health and Welfare (MOHW)	Korea Institute of Health Service Management (KIHM)	Medical care	1995
Agriculture and Forestry (MAF)	R&D Promotion Center for Agriculture, Forestry and Fishery (ARPC)	Agriculture, Forestry and Fishery	1995
Environment (MOEn)	National Institute of Environmental Research (NIER)	Environment	1992
Education (MOEd)	Korea Research Foundation(KRF)	Academic research	1996

S&T policy in Korea had lacked integrity of S&T planning. This was mainly due to the diversified system in S&T policy-making. The foresight process took about one year and more than 400 experts had participated from industry, academe and government. The foresight procedure included three stages, i.e., preliminary stage, main foresight, which consisted of four phases, and the commitment stage.

In brief, at the preliminary stage, coordination and communication for new national program were made between ministries including various interest groups. The foresight committee was also constructed. Next, at the main foresight, there were four phases. It included reviewing information about factors related to science technology, addressing the objectives of R&D program and selecting the candidate technologies for the R&D program. A survey for the candidate technologies was undertaken for priority setting, and finally the committees selected 11 technologies. Budget allocation, control and R&D evaluation were followed at the final stage.[11]

An evaluation of the HAN projects after 3 years showed that the HAN projects turned out to be quite successful. This has been a standard model for the S&T policy and formulating national R&D program. A primary lesson from the foresight of HAN projects places an emphasis on the concerted action among different interest group and resource allocation by priority setting. Such a framework seems now to be inevitable and is frequently employed for major policy making, which was also employed when the MOST initiated to enact the S&T special law in 1997—targeting a substantial increase in S&T capability for next 5 years through the five-year plan for S&T development.

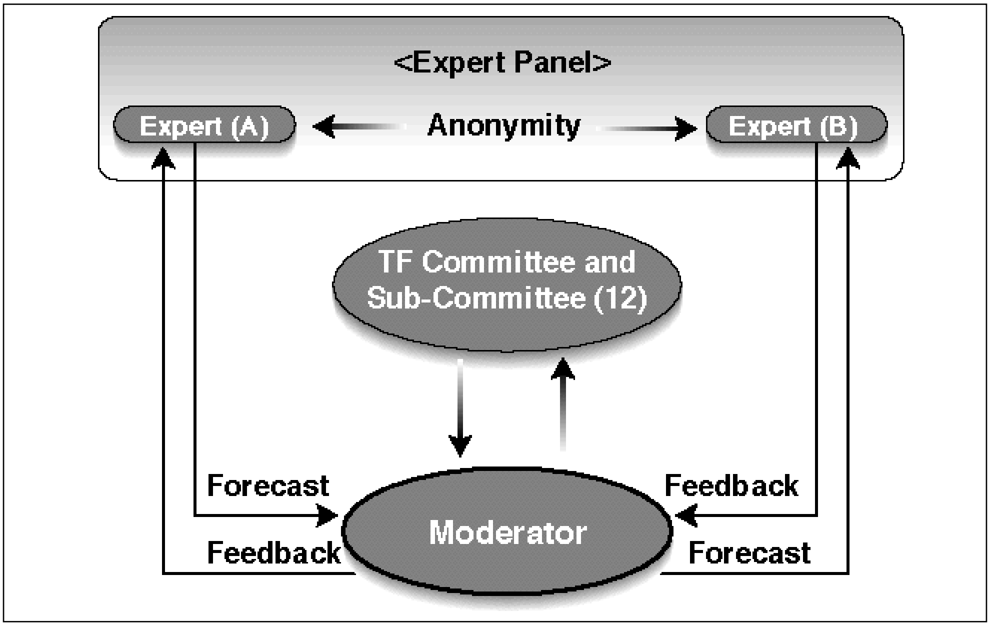
Fig. 1 Foresight Framework of HAN Projects.



Source: T. Shin & H. Kim [11].

However, since only limited number of experts participate in such foresight activities, it is required that formulation of new R&D program should be based upon more extensive information produced in a systematic way as well as supported by wide-ranging consensus among related actors in socio-economic system.

Fig. 2 Organization of Korean Delphi.



Source: T. Shin [10].

It was not until the late 1980s that a major concern on the technology forecasting was made firstly by a research team of the Science and Technology Policy Institute (STEPI) in Korea, affiliated to KIST. Since then, an attention had been paid constantly, but not rigorously—mainly due to a small number of TF experts and lack of research fund at the beginning. There had been a series of efforts for technology forecasting in early 1990s.* In 1992, the research team was able to carry out a Delphi study for a long-range technology forecasting.[12] The Korean Delphi, characterized as three-round Delphi, was undertaken through three stages including preliminary activities, pre-foresight and main foresight. Martin & Irvine[7] divided foresight activities into pre-foresight, main foresight and post-foresight. However, since the Korean Delphi focused mainly on production of S&T information, the post-foresight activity was not carried out. The Korean Delphi provided a major information to various policy formulations afterward, and stimulated substantially other R&D management agencies.

3.3. Others

On the other hand, MOTIE has undertaken R&D programs related to industrial activities for last 10 years. Under the umbrella of MOTIE, non-profit research institute, the Korea Institute of Industrial Technology (KITECH) is responsible for industrial R&D. The KITECH established the Institute of Industrial Technology Policy (ITEP). The ITEP is responsible for management of R&D funded by the MOTIE, including selection of technologies, fund allocation, and evaluation, etc. For effective performance of industrial R&D, ITEP regularly undertake technology foresight. Its foresight activities focus mainly on problem solving in the short term, usually less than 10 years. Its foresight activities depend by and large on regular survey for industrial sector, finding technologies needed by industries. In so doing, major criteria in selection new technologies are generic and core industrial technologies, import-substitution technologies, technologies creating high value-added, and environmentally friendly technologies, etc. When its operation is mainly based on industrial concerns, a bias might be made, since small and medium enterprises do not have relevant information about technologies. Thus, ITEP also makes continuing effort to develop methodologies and to refine its foresight activities for the relevancy. Primary purpose of ITEP's current foresight activities is to find out technological opportunities and to set the priority over competing opportunities, upon which the five-year plan for development of industrial technology 1996-2000 will be revised.

Although MIC started its own R&D operation in the beginning of 1990s, the investment in the information technologies has been sizable. It took over one of NPRIs, Electronics and Telecommunication Research Institute (ETRI), from MOST to concentrate more on information technologies. Under the umbrella of ETRI, the Institute of Information Technology Assessment (IITA) is responsible for technology foresight. IITA undertakes technology foresight activities focusing more on the normative approach in particular. MIC has pursued a policy for information technology, making a sizable investment in constructing national super highways by 2010. If such investment is in schedule, communication services to provide are greatly concerned. Therefore, in case of IITA, the demand side of technologies is one major factor to be taken into account when the R&D plan is formulated. On the other hand, (component) technologies to make new services feasible may be addressed partly in S&T-push approach.

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* There were patient efforts devoted by the research team, as being stimulated and motivated by the Japanese Delphi. The research team invited experts, such as Mr. Irvine from the United Kingdom, Mr. Kondo Satoru from Japan and Professor Martino from the United States, to learn about technology forecasting, and continuous seminars and discussions were made by themselves.

Thus, it is well observed that TF activities of R&D organizations are closely related to their own situations. Some place an emphasis on producing the S&T information simply for addressing S&T opportunities, while some do on the strategy formulation in their R&D activities. Somehow, this type of activities is the effort to adopt a proactive and rational approach to S&T activities including S&T resource allocation.

The private sector was greatly influenced by the first Korean Delphi. Large-scale firms, among others, have paid greater attention to it, since their R&D investments keep increasing. For example, the Korea Electric and Power Corporation (KEPCO) carried out in 1995 a Delphi for its long-term R&D planning with an assistance of the research team of the STEPI. About 400 topics in the area of electricity were dealt with for next 30 years. The Samsung and LG on the other hand established and run their own team for technology forecasting in line with R&D management. Their major role is known as overall surveillance of S&T opportunities and formulation of S&T strategies. Recently, Samsung carried out technology foresight with a consultation of the Mitsubishi Research Institute. In this exercise, market forecast was taken into account for technology forecasting; using Delphi, statistical analysis and documentation of available information, in combination.

However, after the technology forecasting was known to the public firstly by the Delphi method, it is hardly accepted for a practice—mainly due to greater costs and limited number of experts available—by many R&D organizations, particularly small organizations. Technology forecasting using other than Delphi has been hardly exercised and reported. Thus, diversification of studies using various methods should be made in the future.

4. Concluding Remarks

So far we have discussed technology foresight and S&T policy making. With the S&T environment changing rapidly, the foresight activity is increasingly important. It is mainly because major concerns of decision-makers move to “what” from “how” in their operations. The history of TF activities in Korea is not long, but quite active in various areas. At the government level, S&T activities are well diversified, which may cause a serious overlap in S&T investment and mislead resource allocation. The individual R&D organization primarily emphasizes priority setting through foresight activities, which is not enough to avoid misallocation of resources at the national level. In a diversified system, the foresight activities at different levels should be fully integrated. Foresight results could be fed vertically and/or horizontally into the process and subsequent foresight efforts. MOST has showed some successful exercises in this line.

In summary, some lessons from Korea’s TF activities can be drawn. First, growing importance of new technology for economic competitiveness and social progress is being increasingly recognized. With research costs rising and technological opportunities expanding, a more systematic approach to priority-setting is inevitable, since no organization can do everything. Second, foresight assumes that there are numerous possible futures. Thus, realization of the future will depend on today’s choice, which emphasizes proactive attitude towards the future. Third, technology foresight includes various factors, such as economic, technological, social/cultural factors, and so on. It implies that process involved in technology foresight cannot be overemphasized, that is, concerted action among different actors is by far important, led by consensus building.

APPENDIX: An Interpretation of the Korean Delphi

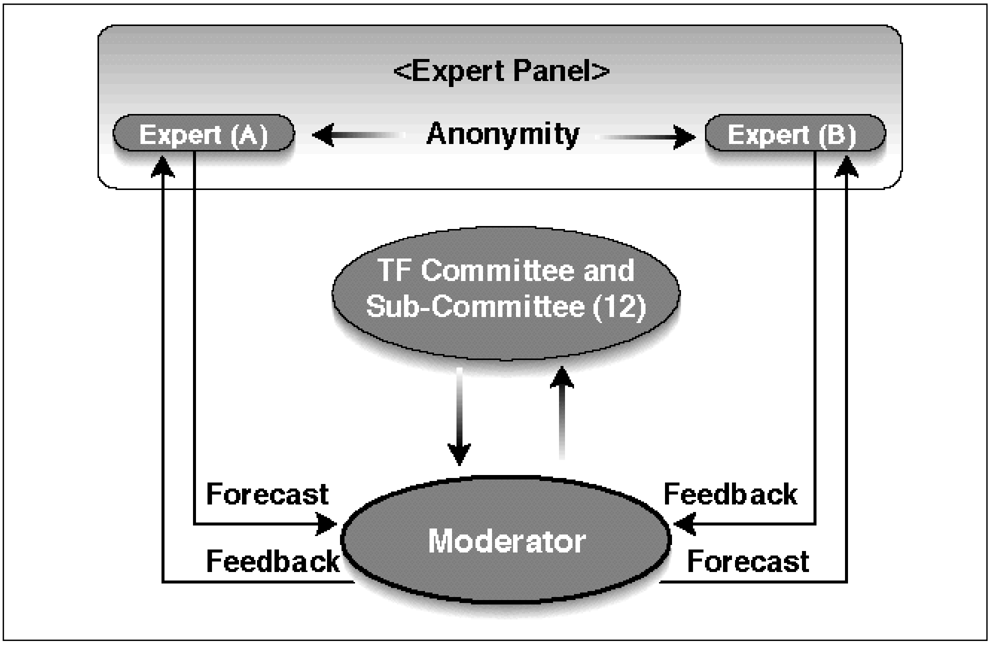
A.1. Overview and Major Outcomes

The Delphi is a well-known method for the technology forecasting; particularly for a long-range and large scale forecasting at a one time.[8] The nation-wide survey for the technology forecasting employed basically the three-round Delphi.** Three rounds were necessary because technological topics for forecasting had to be selected with relevancy to the Korean society.

At the first round, thus, ideas of experts were collected in the science and technology community of Korea. It was thought that those topics, which have been forecasted in other countries, might not be appropriate in this country. Because the technology capability of Korea as a developing country must significantly differ from those of advanced countries. Technological concerns and attentions of the Korean experts must be influenced by factors unique to Korea.

The blank papers were sent to about 25,000 experts and asked them to send back their ideas if anything valuable for and relevant to the Korean society, to forecast over next 20 years. About 5,000 experts has suggested about 30,000 ideas were suggested altogether. Out of them, about 9,000 topics were selected and rearranged into 15 areas. Those areas were (1) *information, electronics and communications technology*, (2) *production*, (3) *materials*, (4) *fine chemicals*, (5) *life science*, (6) *agriculture, forestry and fisheries*, (7) *medical care and health*, (8) *energy*, (9) *environment and safety*, (10) *minerals and water resources*, (11) *urbanization, construction and civil engineering*, (12) *transportation*, (13) *marine and earth science*, (14) *astronomy and space*, and (15) *ultra technology*.

Fig. A1 Organization of Korean Delphi.



Source: T. Shin [10].

** A more comprehensive discussion is provided in T. Shin [10].

On the other hand, TF committee was constructed for the overall decision making and 12 sub-committees for covering 15 areas of technologies. The TF committee was necessary because the moderator did not have expertise in all areas of technologies. Total number of experts for the committees were 91 persons; 18 from industries, 48 from universities, 24 from NPRIs (non-profit research institutes) and 1 from the government. Activities of the committees were mainly focused on selecting of topics to be forecasted out of those 9,000 topics and reviewing of verbal descriptions of each topic. The committees selected 1,127 topics, which were manageable for the survey. Basically, all such activities at the first round were related to dealing with "what to forecast."

Table A1 Technological Topics by Area and Stage of Innovation.

	Elucidation	Development	Practical Use	Widespread Use	Total
1. Information, electronics & communications	4	56	56	9	125
2. Production	1	69	35	10	115
3. Materials	2	66	57	6	131
4. Fine chemicals	3	40	7	1	51
5. Life science	21	51	17	3	92
6. Agriculture, fishery & forestry	16	33	28	6	83
7. Medical care & health	33	52	27	5	117
8. Energy	1	39	36	11	87
9. Environment & safety	9	48	22	6	85
10. Minerals & water resources	6	25	17	6	62
11. Urbanization, construction & civil engineering	3	36	17	6	62
12. Transportation	0	39	34	7	80
13. Marine & earth science	8	24	12	2	46
14. Astronomy & space	0	11	13	0	24
15. Ultra technologies	1	7	15	3	26
Total	**108**	**596**	**393**	**77**	**1174**

Note: Figures are the number of topics

Source: T. Shin, J. Park, K. Jung & H. Kim.[12]

At the second round, entire questionnaires were sent to about 5,000 experts who already expressed their willingness to join the long-range technology forecasting. The return rate of questionnaires was 32.4%, i.e., 1,590 experts responded at the second round. On the other hand, 47 topics suggested additionally at the second round were added to the third round, and finally the survey ended up with 1,198 (75.3%) respondents. Out of them, about 54% of those experts worked for universities; about 30% for public sector including NPRIs and about 16% for industry. Such a distribution of experts over the professional works is a good reflection of the distribution of R&D manpower in Korea. On the other hand, more than 60% of those experts had experiences in their field for more than 10 years, and more than 80% have Ph. D s in their education.

Table A2 Distribution of Topics by Forecast Time.

	Before 1995		1996-2000		2001-2005		2006-2010		2011-2015		After 2016	
	K	W	K	W	K	W	K	W	K	W	K	W
1. Information, electronics & communications	0	0	31	90	81	31	11	3	2	1	0	0
2. Production	0	0	13	27	93	17	9	1	0	0	0	0
3. Materials	0	1	2	82	98	46	31	2	0	0	0	0
4. Fine chemicals	0	0	1	30	35	21	14	0	1	0	0	0
5. Life science	0	0	0	23	34	50	38	19	19	0	1	0
6. Agriculture, fishery & forestry	0	0	17	41	41	40	25	2	0	0	0	0
7. Medical care & health	0	0	3	19	47	82	58	16	9	0	0	0
8. Energy	0	0	5	57	53	27	26	3	2	0	1	0
9. Environment & safety	0	1	11	62	56	21	17	1	1	0	0	0
10. Minerals & water resources	0	1	15	46	33	3	2	0	0	0	0	0
11. Urbanization, construction & civil engineering	0	2	7	52	47	8	8	0	0	0	0	0
12. Transportation	0	9	23	59	46	12	10	0	1	0	0	0
13. Marine & earth science	0	0	6	25	20	21	20	0	0	0	0	0
14. Astronomy & space	0	14	2	9	13	0	6	21	3	0	0	0
15. Ultra technologies	0	2	2	19	14	5	9	0	1	0	0	0
Total	**0**	**30**	**138**	**711**	**711**	**384**	**284**	**48**	**39**	**1**	**2**	**0**

Note: 1. 'K' denotes Korea, and 'W' the world leader
2. Figures are the number of topics

Source:T. Shin, J. Park, K. Jung & H. Kim.[12]

From the Delphi results, the forecast time of each topic was obtained by the median year of the inter-quartile range. As shown in Table. 3, it can be seen that most topics expected to be realized within next 10 years. 711 topics expected to be realized in Korea between 2001 and 2005, while 711 topics expected to be realized in the world leader between 1996 and 2000. On the other hand, the dispersion of forecast time was measured by the distance between the upper and the lower quartiles. This is an indication of convergence of expert's opinions. If the distance is greater, therefore, estimation of forecast time splits between experts, showing less accuracy. About 70.5% of all topics show less than 5 years in their distance.

A.2. S&T Development Paths

In this section, an attempt is provided to seek Korea's S&T development paths. Based on the estimated time of realization of Delphi topics, it would be possible, with several assumptions, to draw an alternative of the future path of science and technology development. In general, the development path of an individual technology can be represented by mapping technical parameter or functional capability onto the time period. For example, the development path of the semi-conductor can be denoted by the curve of the degree of integration or speed of data processing along with the time period.

However, at the national level, it might be defined in a different way. S&T development of a country implies the increase in the country's capability of creation,

Table A3 Dispersion of Forecast Time (Korea).

	Distance between upper and lower quartiles				Total
	1-3 years	4-5 years	6-10 years	More than 11 years	
1. Information, electronics & communications	19	81	25	0	125
2. Production	18	79	18	0	115
3. Materials	25	95	11	0	131
4. Fine chemicals	7	22	22	0	51
5. Life science	3	49	40	0	92
6. Agriculture, fishery & forestry	5	45	33	0	83
7. Medical care & health	5	37	73	2	117
8. Energy	13	54	20	0	87
9. Environment & safety	7	45	33	0	50
10. Minerals & water resources	14	25	11	0	50
11. Urbanization, construction & civil engineering	9	39	14	0	62
12. Transportation	31	39	10	0	80
13. Marine & earth science	9	21	16	0	46
14. Astronomy & space	3	14	6	1	24
15. Ultra technologies	4	11	11	0	26
Total	**172**	**656**	**343**	**3**	**1174**

Note: Figures are the number of topics
Source: T. Shin, J. Park, K. Jung & H. Kim.[12]

application and deployment of S&T knowledges. It will be influenced by S&T inputs primarily. However, no systematic behavior is known in linkage from S&T inputs to outputs. When an attempt to measure S&T development, therefore, it is arguable whether S&T inputs or outputs are employed. In any case, if a country is able to acquire technologies in consideration over time, S&T assets of the country will be accumulated, in turn, implying the country's S&T progress. Thus, it could be said that cumulative number of technologies acquired in any innovation stage by a country along time period represents the S&T development path at the national level, reflecting aggregation of progress of individual technologies.

To obtain S&T development paths, the followings are assumed,

(1) The stationary state is assumed over next 20 years. That is, there would be no drastic changes in the Korean society such as south-north unification, major natural disaster, and others.

(2) Those 1174 topics represent necessary technologies for S&T development in Korea. It can be said that necessary technologies will appear additionally in time, but at the time point of forecasting, they are the technologies in consideration, upon which the expected time path can be drawn out.

(3) Presuming an imaginary world leader country so that a comparison of Korea's current position can be made. Such a world leader country is in fact a combination of several countries most advanced in science and technology.

Table A4 Slopes of S&T Development Paths.

		Constant	Slope
All Areas	Korea	-210645 (-18.6)	105.406 (18.6)
	World leader	-174071 (-10.4)	87.311 (10.5)
1. Information, electronics, & communications	Korea	-22152 (-11.0)	11.093 (11.0)
	World leader	-15579 (-5.00)	7.824 (5.03)
2. Production	Korea	-20969 (-7.20)	10.500 (7.23)
	World leader	-22755 (-4.68)	11.412 (4.70)
3. Materials	Korea	-30051 (-10.5)	15.027 (10.5)
	World leader	-30369 (-4.96)	15.217 (4.98)
4. Fine chemicals	Korea	-10634 (-11.6)	5.318 (11.6)
	World leader	-16835 (-7.96)	8.429 (7.97)
5. Life science	Korea	-15007 (-7.89)	7.497 (7.91)
	World leader	-15463 (-13.7)	7.742 (13.8)
6. Agriculture. Fishery & forestry	Korea	-14547 (-16.8)	7.280 (16.9)
	World leader	-20522 (-10.9)	10.273 (10.9)
7. Medical care & health	Korea	-22989 (-18.3)	11.491 (18.3)
	World leader	-21720 (-12.2)	10.874 (12.2)
8. Energy	Korea	-17234 (-12.1)	8.618 (12.1)
	World leader	-12794 (-7.40)	6.418 (7.43)
9. Environment & safety	Korea	-15805 (-11.4)	7.909 (11.4)
	World leader	-17188 (-7.45)	8.615 (7.47)
10. Minerals & water resources	Korea	-8930 (-9.50)	4.473 (9.54)
	World leader	-10596 (-5.46)	5.317 (5.48)
11. Urbanization, construction & civil engineering	Korea	-10384 (-7.98)	5.200 (8.02)
	World leader	-13708 (-6.39)	6.873 (6.41)
12. Transportation	Korea	-12785 (-8.89)	6.406 (8.93)
	World leader	-16754 (-9.70)	8.406 (9.73)
13. Marine & earth science	Korea	-8652 (-12.2)	4.327 (12.3)
	World leader	-12212 (-9.14)	6.117 (9.16)
14. Astronomy & space	Korea	-4074 (-11.5)	2.038 (11.5)
	World leader	-1686 (-7.52)	0.853 (7.61)
15. Ultra technologies	Korea	-5036 (-13.9)	2.518 (14.0)
	World leader	-7383 (-9.26)	3.700 (9.28)

Note: 1. Figures are estimation results of the equation, $NT_i = a_0 + a_1T + e$, (i = Korea, World leader), where NT and T denote the cumulative number of technologies and time, respectively.

2. Figures in the parentheses are t-values.

(4) Since the forecast time estimated are distributed mostly around 2005, outliers beyond 2011 are discarded in estimation of the S&T development path.

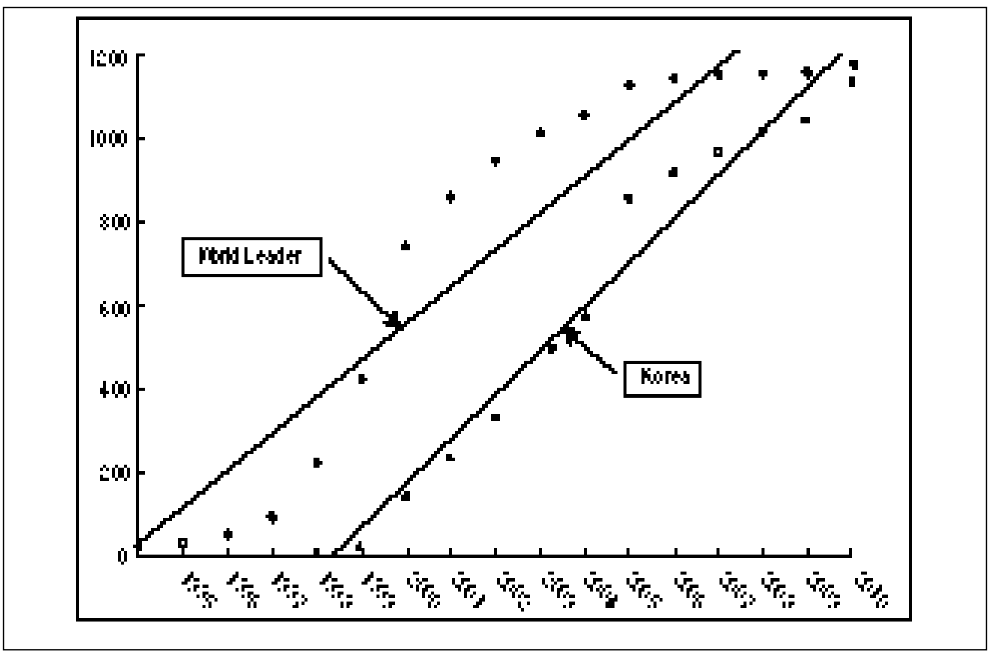
(5) The S&T development path is approximated linearly. Since no additional topics are considered as time passes, there is a tendency to converge both forecast times of world leader and Korea toward the saturation. The linear path will show the development pattern on average of the entire time period.

Under those assumptions, it will be possible to address paths of science and technology development, represented by those topics, based upon expert's opinions obtained systematically. Since social impacts of the topics differ upon realization, however, it does not imply that such S&T development is directly related to social well-beings and / or country's economic competitiveness; but they may move to the same direction. On the other hand, since such paths do not take account of additional technologies newly emerged in time, it will be therefore desirable to follow them up by regularly undertaking the Delphi survey. If this can be done regularly, it will provide a useful measure of performance of S&T policies and guidance of investment.

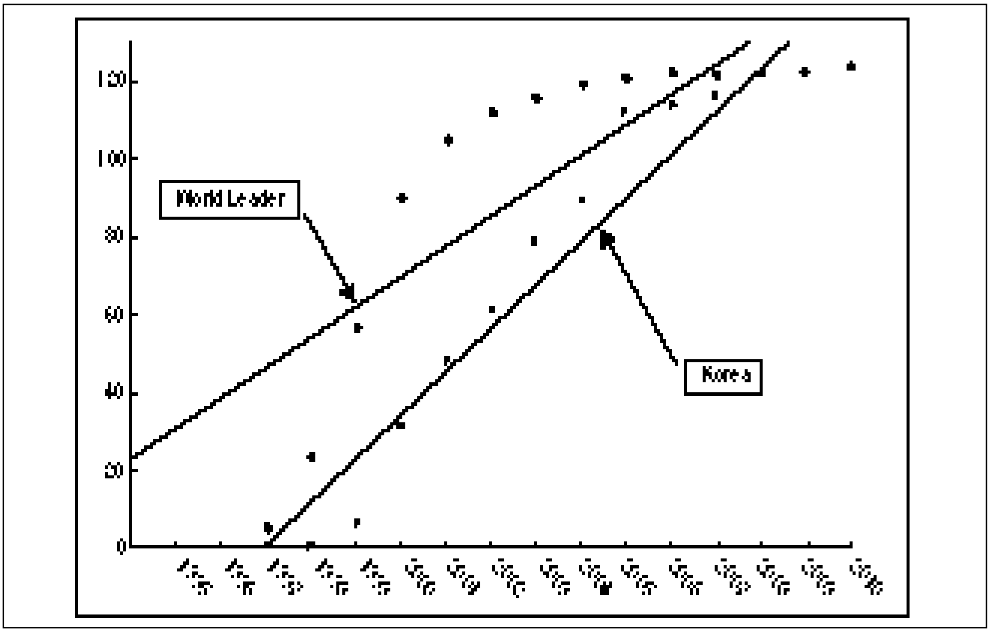
The S&T development paths can be shown by areas in a series of figures, Table A4 and Fig. A2. In Fig. A2, the 'diamond' denotes the forecast time of world leader country and 'circle' that of Korea, by the panel experts. The linear curve can be obtained, by regressing the cumulative number of topics realized onto the time period. Then, the slope of the estimated curve represents the speed or rate of change of S&T progress. If the slope is the greater, the faster is the development of science and technology in the country. The slope of the curve can be influenced by S&T policies, such as R&D investment, manpower, knowledge transfer mechanism, efficiency of the national innovation system, and others.

Fig. A2 S&T Development Paths of Korea.

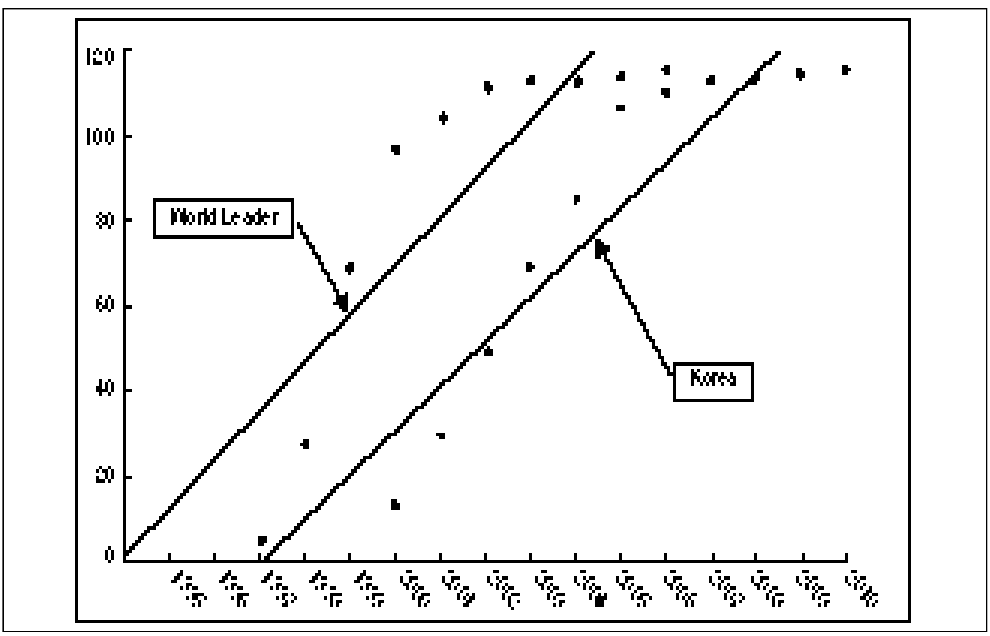
All Areas
(1174 Topics)



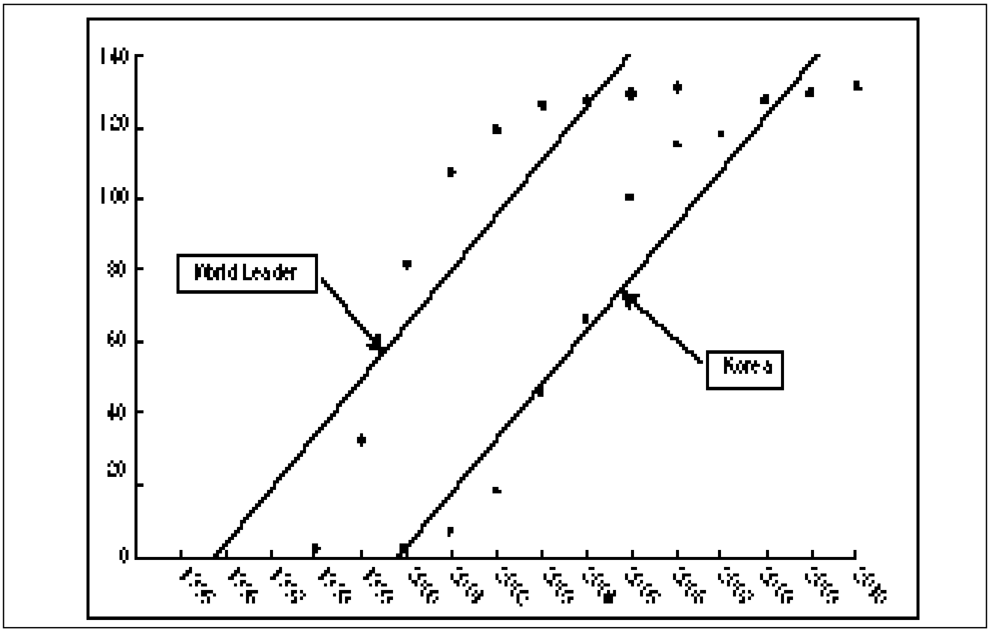
1. Information, Electronics and Communications
(125 Topics)



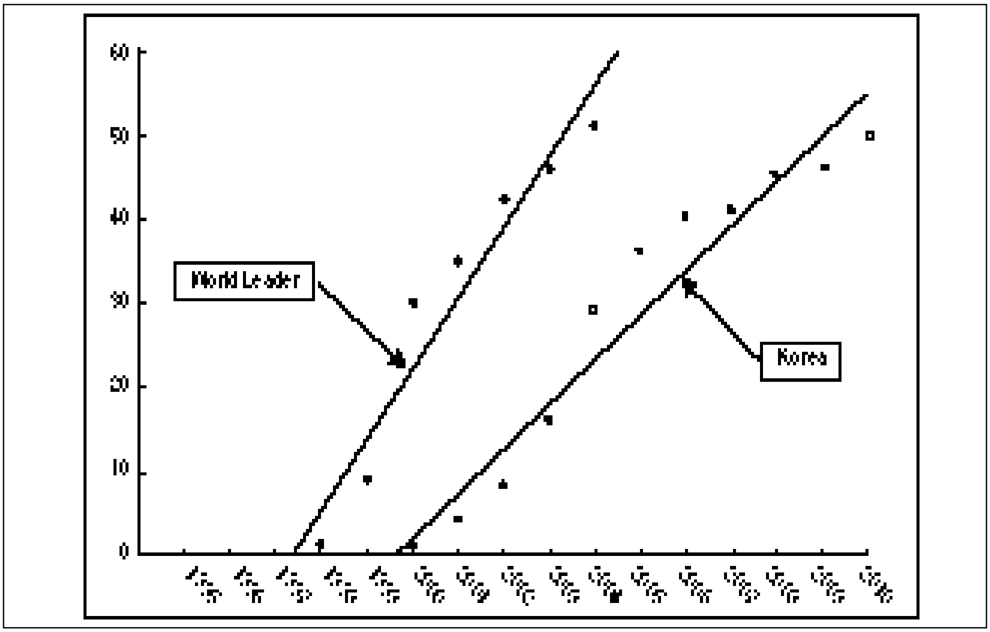
2. Production
(115 Topics)



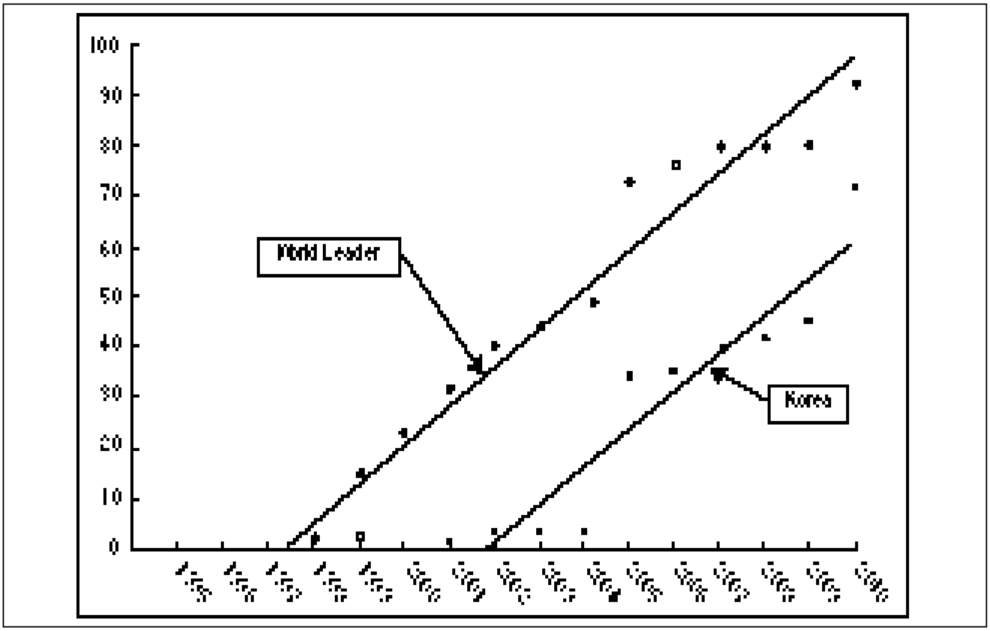
3. Materials
(115 Topics)



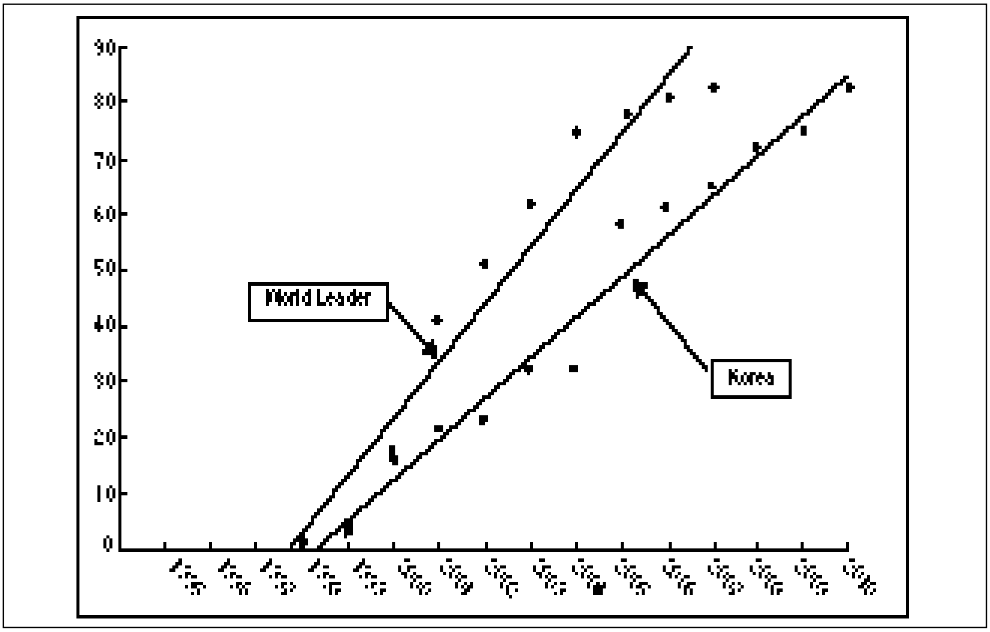
4. Fine Chemicals
(51 Topics)



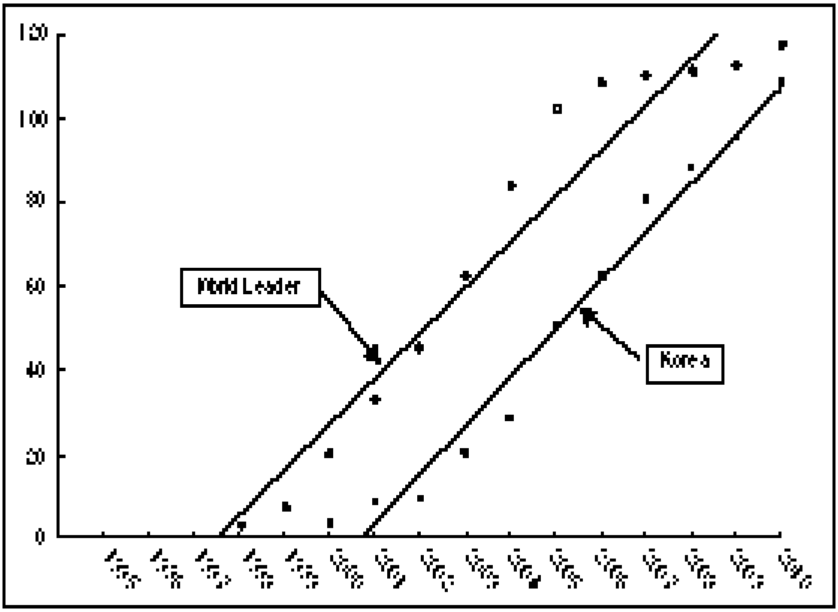
5. Life Science
(92 Topics)



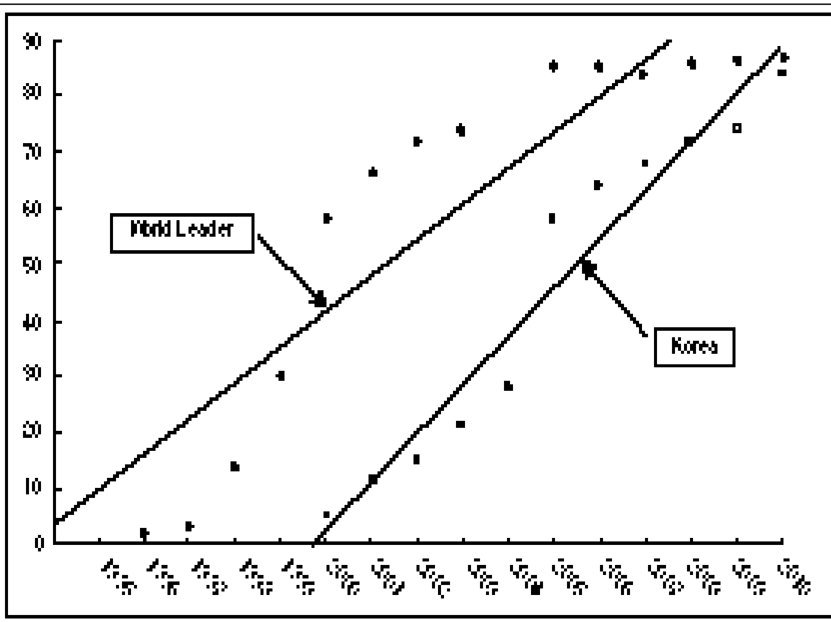
6. Agriculture, Fishery and Forestry
(83 Topics)



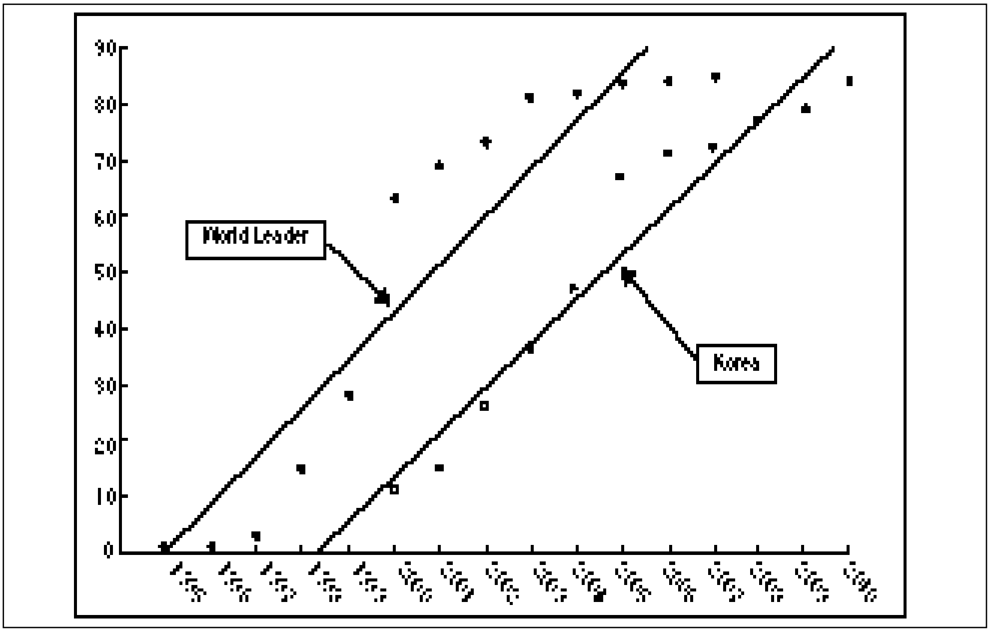
7. Medical Care and Health
(117 Topics)



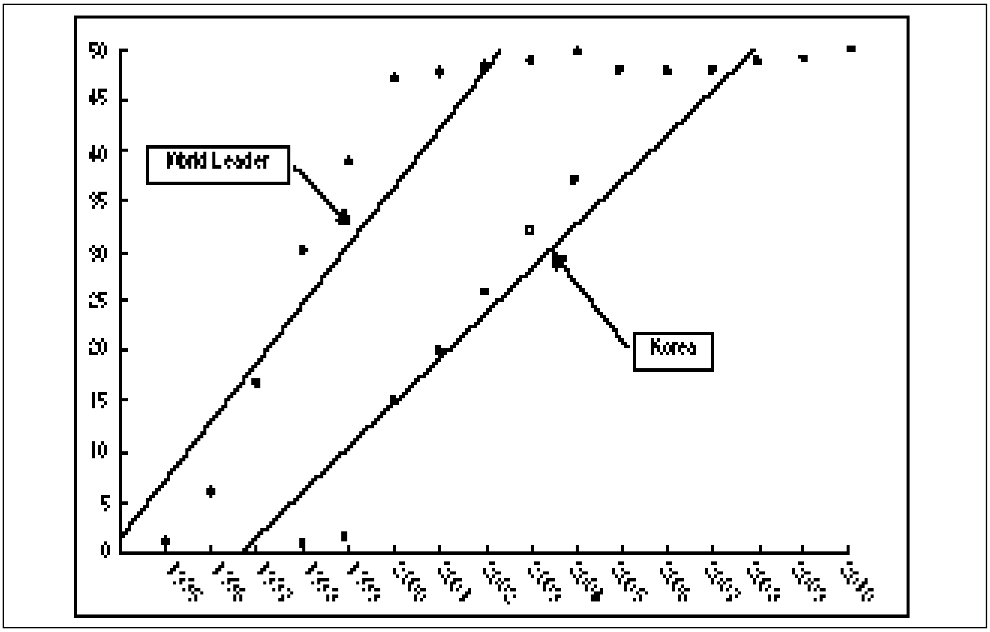
8. Energy
(87 Topics)



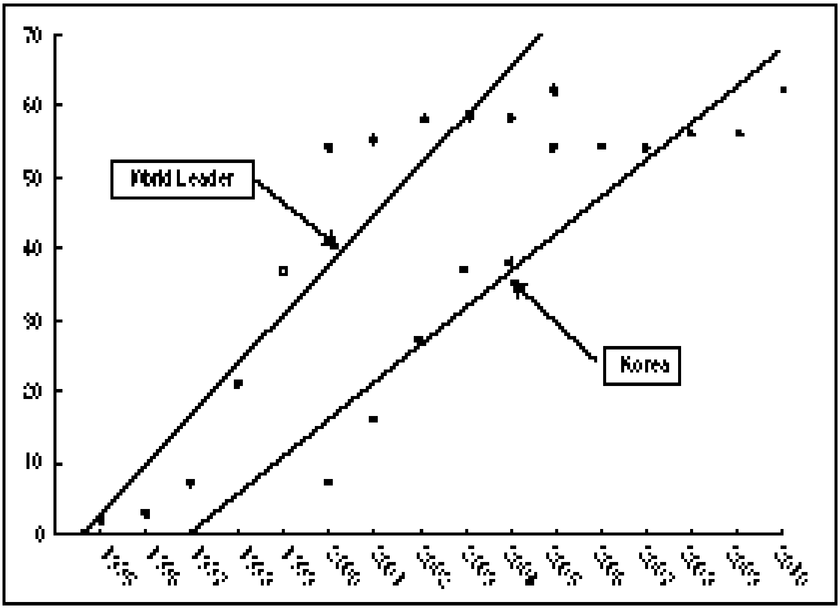
9. Environment and Safety
(85 Topics)



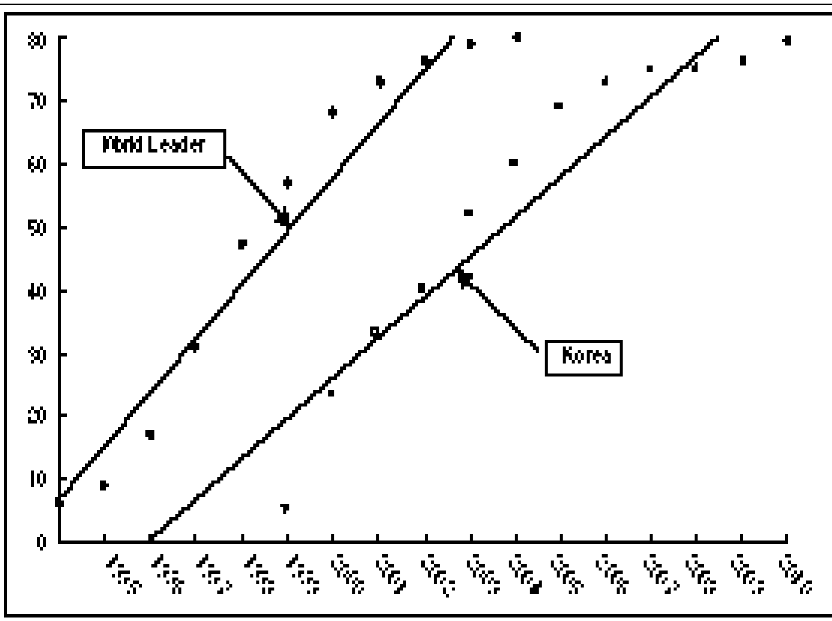
10. Minerals and Water Resources
(50 Topics)



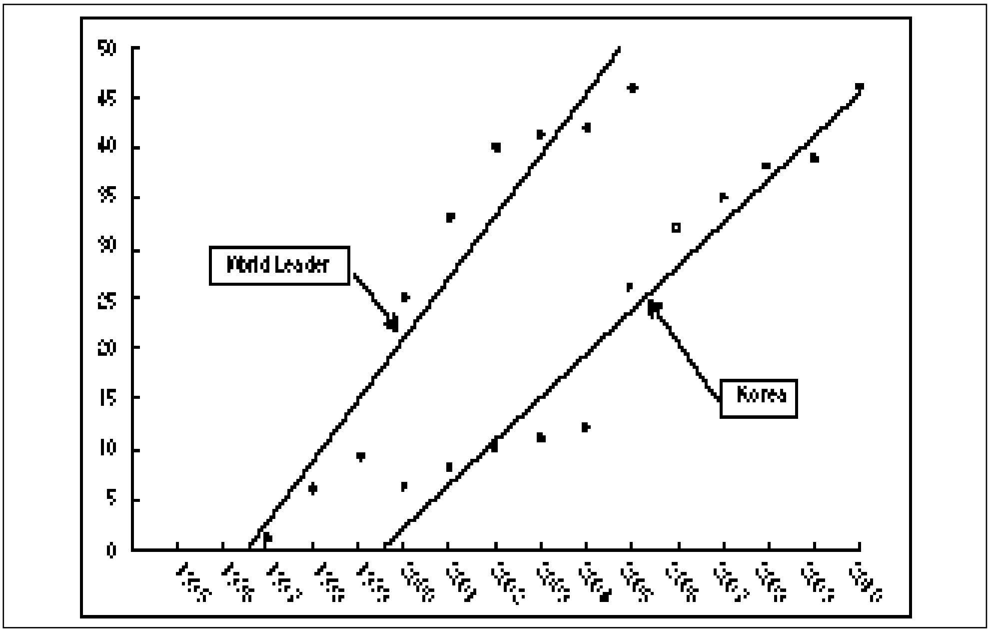
11. Urbanization, Construction and Civil Engineering
(62 Topics)



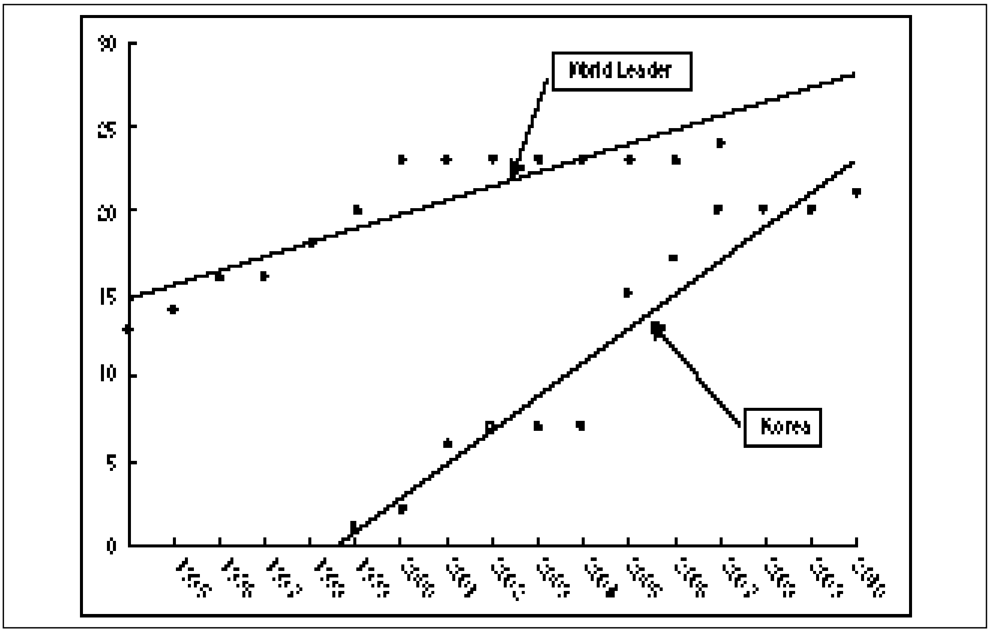
12. Transportation
(80 Topics)



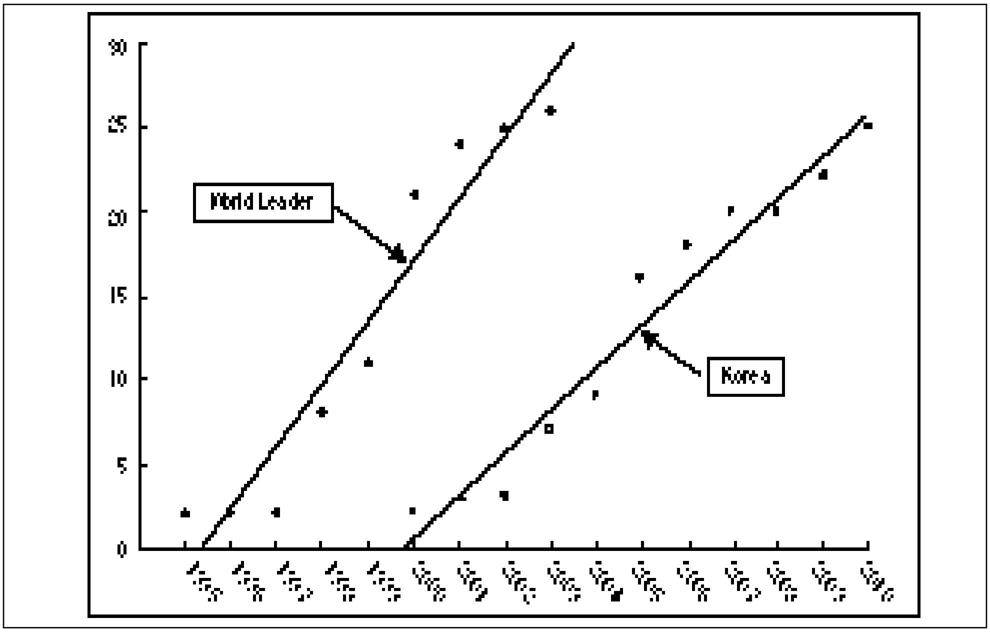
13. Marine and Earth Science
(46 Topics)



14. Astronomy and Space
(24 Topics)



15. Ultra Technologies
(26 Topics)



It is shown from Table 5 and Fig. 3 that Korea's S&T development moves a little faster on the whole relative to the world leader, catching up by about one year in 15 years. The path slopes of Korea and the world leader are 105.406 and 87.311, respectively, implying that, on average, about 105 topics a year would be realized in Korea, while about 87 topics in the world by 2010. It is also shown, by areas, that Korea is catching up the world leader country fast in the areas of *information, electronics and communications; energy; medical care & health;* and *astronomy*, showing greater slopes of the estimated curves than the world leader's. In particular, the Korea's slope (11.093) of the area of *information, electronics & communications* is much faster than the world leader's (7.824). Although the Korea's slope of the area of *astronomy* is greater than the world leader's, more than a half of topics are already realized in the world leader. Therefore, Korea's catching up must be faster by simply transferring and implementing advanced technologies from the world leader.

But most other areas falls behind increasingly, such areas of *production; materials; fine chemicals; life science; agriculture, fishery & forestry; environment & safety; minerals & water resources; urbanization, construction & civil engineering; transportation; marine & earth science*; and *ultra technologies*. Their slopes are lower than the world leader's. It is noted that Korea in the area of *production* keeps falling behind the world leader, although they are more related to competitiveness of the Korean industries.

An immediate policy implication from the results is whether Korea takes balanced-development strategy or imbalanced-development strategy. That is, with the limited resources, Korea might pursue strategically a few areas with more investment, to catch up the world leader in those areas. In this case, a careful assessment of each area should be made for more resource allocation, and consequently imbalance between the areas will widen increasingly. Otherwise, Korea might pursue S&T development with a balance over various areas. In this case, Korea should make more investment in the areas falling far behind the world leader country.

A.3. CONCLUDING REMARKS

The Korean Delphi was firstly carried out to provide more extensive information with wide-ranging consensus of the society. The purpose of the Korean Delphi is only to produce decision information, so that the post-foresight of planning did not follow. It has drawn a good deal of attention by the public and private organizations. However, TF studies using other than Delphi are rarely exercised so far. The way to formulate S&T strategies might differ from organization to organization, so that various methods should be employed and exercised.

An interpretation of results of the Korean Delphi is provided in seeking expected paths of S&T development in Korea with a comparison of the world leader country. The paths are shown by areas with some implications. They can be obtained by innovation stages, such as elucidation, development, practical use and widespread use stages, from which useful policy implications can be drawn. It is also pointed out that the estimated paths might be regularly revised following continuing Delphi's.

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Technology Foresight Applications in the Private Sector

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Industry's Concern with the Future

Industrial firms have always had a need, and a desire to be able to predict or know about the future, and hence be able to control it. Since time immemorial prediction of the weather has been crucial to agriculture and to trade. (Remember, it is the reported loss of Antonio's merchant ships in a storm at sea that triggers Shylock's claim in the Merchant of Venice).

This has grown today into a vast industry. Sherden[1] argues that:

each year the prediction industry showers us with $200 billion in (mostly erroneous) information. The forecasting track records for all types of experts are universally poor, whether we consider scientifically oriented professionals, such as economists, demographers, meteorologists, and seismologists, or psychic and astrological forecasters whose names are household words.

In fact, these experts whose advice we pay handsomely for *routinely* fail to predict the major events that shape our world, or even the major turning points - the transition from status quo to something new - whether it be the economy, stock market, weather or new technologies.

There is abundant evidence that despite, and because of, these many failures, the demand in industry for more effective ways of addressing the future continues to grow. A survey of the major recognised management 'gurus' reveals a very strong emphasis on developing new approaches to managing for the future:

What business practitioners - as well as their economists and advisers - will need is an even more comprehensive model of the oncoming Third Wave reality, not just focusing on economics and management issues, but showing how these must respond to social, technological, political, cultural and religious shocks - of which there will be plenty in the years immediately ahead.[2]

Thus:

- *You can't look at the future as a continuation of the past...because the future is going to be different. We really have to unlearn the way we dealt with the past in order to deal with the future... The great excitement of the future is that we can shape it.* (Charles Handy)
- *Tomorrow's successful leaders will value principles more than they value their companies... In the global economy you cannot compete if you don't have high quality and low cost. And you cannot achieve high quality and low cost without a 'high trust' culture. It is high trust that gives you the ability to make meaningful partnerships inside and outside the organisation.* (Stephen Covey)
- *The important thing is to try to shape the nature of competition, to take control of your own destiny... It's not just a matter of being better at what you do - it's a matter of being different at what you do.* (Michael Porter)
- *Competing for the future is about competing for opportunity share rather than market share... In a corporate sense, a strategic architecture is the link between the present and the future. It tells you which new competences you should be building, what new customer groups you should be trying to understand, which new distribution channels you should be exploring.* (C.K. Prahalad)
- *You cannot create the future using the old strategy tools...There is a need to reinvent the basis for competition, and to do that you have to become different as a company...The big challenge in creating the future is not predicting the future; instead the goal is to try to imagine a future that is plausible, that you can create...There are no proprietary data about the future...Most of what a company needs to learn about the future it is going to learn outside of its own industry.*(Gary Hamel)
- *The traditional concept of management is reaching the end of the road. The notion of management as a significant idea in itself, and as a major part of the organization, is obsolete...The real work, the added value, is in the work being performed by the teams of professionals...Every individual on the team is focused on the shared objective, which involves cooperating with others while performing your own particular set of duties.* (Michael Hammer)
- *As we approach the twenty-first century, I see three distinct driving forces: first, there's technology. Then there's the globalization of business. But the third is probably the most challenging. It concerns the unprecedented growth of total material throughput due to all industrial activity on a global scale, the consequent stress on natural systems, and increasing complexity and interdependence...We are out of control, facing a hierarchical nervous breakdown, consequent on running an economic system that violates the basic laws of natural systems* (Peter Senge)
- *Today, technological progress is more or less a production process - if you put more money and good people into a particular area where there is a solid foundation, technological progress is more or less guaranteed. The really big issues facing mankind concern our inability to understand and manage our complex human systems* (Jay Forester)
- *The major challenge for leaders in the twenty-first century will be how to release the brainpower of their organizations* (Warren Bennis)

- *I think the idea that all of Asia is booming and that it is going to inherit the earth is a little premature, to say the least* (Lester Thurow)

The general themes which emerge of those of great uncertainty, a period of significant qualitative change in structures and attitudes associated to the past is no guide to the future, and the need for organisations and management to move towards very different models of operation to deal with this uncertainty and change.

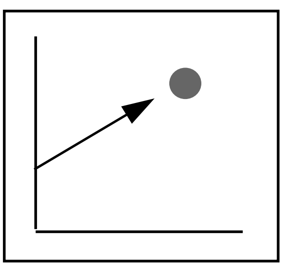
This concern about managing uncertainty is reflected in an article in a recent Harvard Business Review[3] which identifies four distinct levels of uncertainty about the future, and different approaches to manage them.

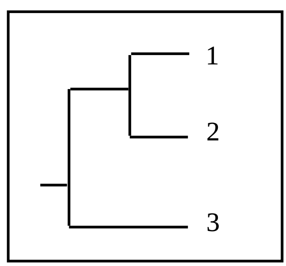
The problem they identify is that the:

- traditional approach leads executives to view uncertainty in a binary way - to assume that the world is either certain, and therefore open to precise predictions about the future, or uncertain, and therefore completely unpredictable. Planning that requires precise forecasts forces managers to bury underlying uncertainties thereby pushing managers to underestimate uncertainty in order to make a compelling case for their strategy...[3]
- At the other extreme, assuming that the world is entirely unpredictable can lead managers to abandon the analytical rigor of their traditional planning processes altogether and base their strategic decisions primarily on gut instinct.[4]

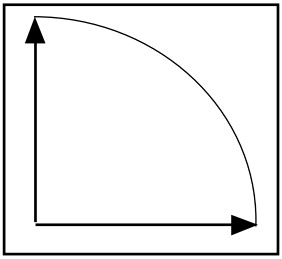
At the first level, a manager can gather sufficient information from market research to make a clear enough forecast to develop a strategy. At the second level some discrete scenarios for alternate futures can be developed. At the third level, a range of possible futures can be identified. They are limited by a number of key variables, but where on that range the outcome will be is in doubt. The fourth level is true ambiguity. Telstra deciding what to do in consumer multimedia is an example.

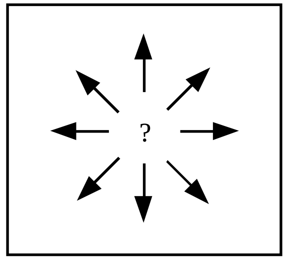
These four approaches are represented in the boxes below.





	1. A Clear-Enough Future	**2. Alternate Futures**
What can be known?	• A single forecast precise enough for determining strategy	• A few discrete outcomes that define the future
Analytic Tools	• "Traditional" strategy tool kit	• Decision analysis • Option valuation models • Game theory
Examples	• Strategy against low-cost airline entrant	• Long-distance telephone carriers' strategy to enter deregulated local-service market • Capacity strategies for chemical plants





	3. A Range of Futures	**4. True Ambiguity**
What can be known?	• A range of possible outcomes, but no natural scenarios	• No basis to forecast the future
Analytic Tools	• Latent-demand research • Technology forecasting • Scenario planning	• Analogies and pattern recognition • Nonlinear dynamic models
Examples	• Entering emerging markets, such as India • Development or acquiring emerging technologies in consumer electronics	• Entering the market for consumer multi-media applications • Entering the Russian market in 1992

What then, is the role for technology forecasting in assisting firms to address these uncertainties?

The Characteristics of Technology Foresight

In its recent form, technology foresight has been driven by and largely developed within the public sector. This largely reflects its association with organisations concerned with public sector research and its management and funding. In addition, the growing awareness of the importance of the emerging knowledge economy and therefore of the value of appropriate investment in the generation of knowledge, has produced a very strong interest in mechanisms that might appear to provide an improved basis for decisions about investment and research.

Thus, technology foresight exercises in the past 10 years have largely been conducted by arms of government for example, STA (Japan), The Office of Science and Technology (UK), The Ministry of Research and Technology (France), The Ministry of Research, Science and Technology (New Zealand), Australian Science, Technology and Engineering Council (Australia). Or they have been carried out by research organisations primarily funded from the public purse; for example the Fraunhofer Institute for Systems in Innovation and Research (Germany), the Science Policy Research Unit (UK), ACIIC (Australia). A related category is that of the committed consulting organisation such as the RAND Institute which has carried out projects for the US Government.

As a consequence the development of technology foresight in the last 10 years has been strongly influenced by its public sector base in consideration of public sector issues.

Martin and Johnston[5] have identified four major drivers of the growth in technology forecasting in recent years. The first of these results from globalisation and growing economic competition. The growth of both markets and producers has put a premium on both innovation and knowledge based industry and services. This in turn has given science and technology a greater importance and thus any tools that can assist in guiding investment in science and technology have become more important.

A second driver, particularly pressing in the public sector, is the increasing set of constraints on government spending. Governments around the world are faced with the twin forces of the declining revenue base (associated with high economic and political costs of deficit budgeting) and growing demands particularly from health and welfare functions. Thus, any public expenditure must be able to be justified and shown to be a valuable investment.

The third driver results from the enormous changes occurring in industrial production: command control management has been replaced by decentralised decision making, empowerment and team operation; the focus on managing the organisation internally has been downgraded to the level of 'company hygiene' and far more attention directed to long term customer-supplier relationships, and the development of strategic alliances and effective networks; the drive for controlled high performance through quality management has been extended by an emphasis on the 'learning' and 'knowledge' organisation; these place an emphasis on developing shared views of the company's future and powerful social mechanisms to promote the means to create it.

The fourth driver is the change in the knowledge production structure and process which according to Gibbons *et al*[6] is characterised by growing transdisciplinary and heterogeneity, in terms of the range of producers of knowledge and with an emphasis on knowledge constructed in the context of application. In this model there is an increasing need for communication, networks, partnerships and collaboration in research, not only among researchers but also between researchers and research users in industry.

To summarise, technology foresight has come to prominence during the 1990s because it fulfils a number of functions:

- it provides a means for making choices in relation to science and technology and for identifying priorities;
- it offers a mechanism for integrating research opportunities with economic and social needs and thereby linking science and technology more closely with innovation, wealth creation and enhanced quality of life; and
- it can help to stimulate communication and to forge partnerships between researchers, research users and research funders.[7]

In addition Martin and Johnston have argued that technology foresight has a crucial role to play in 'wiring up', or strengthening the connections within national innovation systems, so that knowledge flows more freely between the constituent actors, and the system as a whole is more effective in learning and innovating:

> *the process benefits associated with the technology foresight activities in Britain, Australia and New Zealand are very much concerned with the fostering of productive long term partnerships - among researchers and among firms, across industrial sectors, and between industry, universities, government and society at large.*[8]

In addition, as a range of foresight projects have demonstrated, important potential innovations and the emerging generic or critical technologies likely to underpin them are characterised by the confluence of the number of component technologies. This creates a need for multidisciplinary and multi-institutional research efforts, though networks and partnerships and effective linkages to financial, legal, commercial and marketing systems.

Foresight Approaches in the Private Sector

There is evidence of a greatly expanded use of scenario planning in the private sector. The energy, information technology and communications, and health industries have all been actively engaged in many countries in exercises considering a range of options for future development. The emergence but uncertain form and future of the knowledge or digital economy has also produced a particular focus for scenario planning.

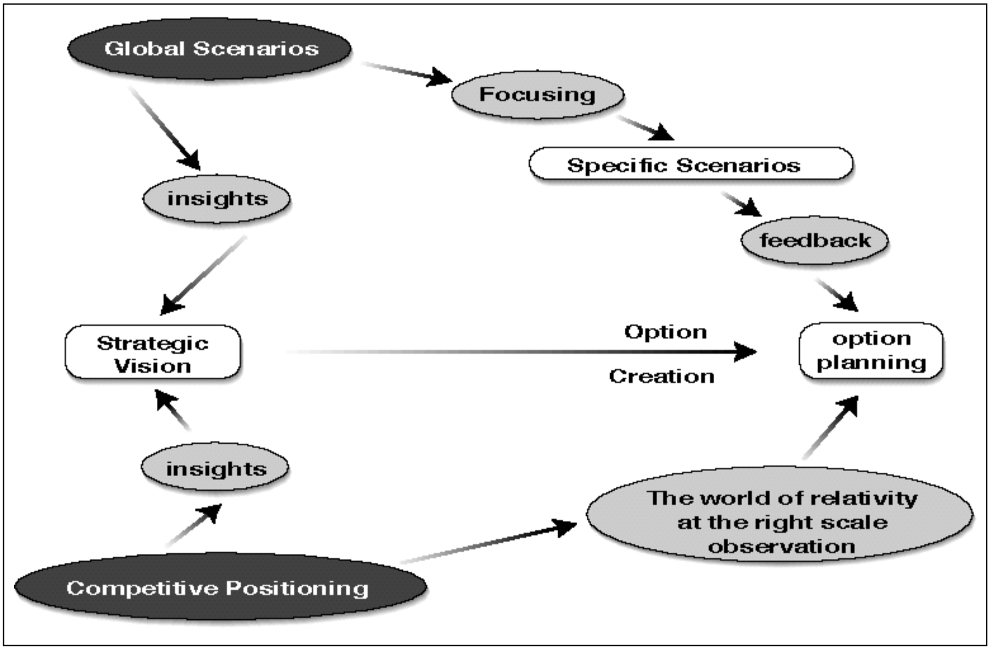
In business, technology foresight can be regarded as a new and specific component of strategic planning and management.

Traditional strategic planning involves:

1. making a commitment to certain goals in order to satisfy the needs of the shareholders, the customers and other interested groups;
2. analysing the company's performance and future prospects in relation to its industry, its markets, and its technologies; and
3. producing a vision, a mission statement, a corporate strategy and other guidelines which are intended to help other management teams around the company to develop and implement their own strategies and plans.[9]

However this approach largely rests on assumed or predicted futures and does not allow for unpredictable step changes. Scenario planning, with its reliance on developing a shared view on a range of possible futures, thus adds an extra dimension to strategic planning.

Price[10] has described Royal Dutch Shell Company's use of scenario-based planning, both in the form of wide-ranging 'global' scenarios, and specific project-, technology-, or market-related scenarios. (see figure below)



An interesting example of industrial use of technology foresight technology techniques is provided by Grupp and Reiss.[11] They report that three years ago Janssen-Cilag, a medium-sized German pharmaceutical company started an internal project called 'Meeting Point Future', to explore the future of the health care system in Germany. The process included workshops, quality circles, conferences and a Delphi survey. The survey covered ten thousand medical practitioners and one thousand other experts in the health care system.

Lessons drawn from this case study were:

> *Firstly it is important to note that this particular Delphi survey was not a singular event but rather it was part of a broader initiative to develop the company's strategic orientation. Secondly, the individual results of the survey have triggered various follow up activities within the company — for example workshops with physicians on selected Delphi items. Thirdly, the survey confirmed very clearly an observation which had been made during several other Delphi surveys: the process of the survey itself is a very valuable aspect since a great number of experts are motivated to think critically about future scenarios which are being favoured or rejected by their peer colleagues. In the health care survey, it became evident, that physicians were much more willing to participate actively in shaping the future health care system than was expected previously. Fourthly, for the company, the benefits of the Delphi survey were not only a gain in information and reputation among its clients. The company also found that its strategies for dealing with challenges of the future became broad company issues which were discussed and supported by many employees thereby contributing to an increase of in-house motivation and identity.*[12]

With regard to the relative value to different technology foresight techniques, Price has assessed their relative merits based on a side-by-side exercise involving Delphi and scenario techniques in Shell. He reports:

> *the Delphi technology worked well, but we learned that the closer we got to consensus, the more some panel members diverged, often for very good reasons, so that closure became difficult. Fundamentally, the Delphi process seeks consensus as a powerful forecasting tool, but it is still a forecast, around someone else's selection of what seem to be the critical questions.*
>
> *In contrast it was found that divergent views could be readily handled using scenarios. Indeed scenarios, by their nature are built around diversity of ideas and alternative possibilities. Perhaps most important, someone else had not identified the critical issues beforehand. Rather there is room for the full exploration of ideas and logics as they are generated by contributors in a scenario workshop.*[13]

A range of advantages and disadvantages, particularly in terms of practical application, is outlined in the Box below.

Some problems with scenarios?

Forecasts

— Managers prefer to use forecasts because they are familiar and simple.

— If a forecast is wrong, the fault is the forecaster's.

— For operational programming, short-term projections are essential.

Scenarios

— What's in the name? Scenarios may be seen as not serious or rigorous.

— Scenarios are often prepared by planners, not owned by managers.

— Scenarios are often confused with "base case" and "sensitivities", or any future projections.

— Scenarios may fail to address key concerns of managers.

— Used by advocates, to "sell" their view of the future.

— Beware processes offered as "patent remedies".

— Only successes are reported, but failures cast a long shadow.

Scenarios are necessarily complex, but must also be rigorous.

An explicit process for linking scenarios to strategic planning and implementation has also been devised. In our experience the translation of the multiple insights of scenarios into practical strategic plans presents one of the greatest difficulties when working within a company. Price has developed a 'scenarios-to-strategy' process, reproduced below.

Agree field of interest and time horizon, then:

— *Diagnosis*

Interviews / synthesis / feedback.

— *Investigation*

Wider interviews / analysis / conceptual issues workshops.

Scenario generation and testing, where appropriate.

— *Decision*

Implications / options / choices of action, in top team workshops.

Action responsibilities and programmes.

— *Implementation*

Project and individual support, as required.

Source: Shell and St. Andrews Management Institute.

Conclusions

1. There is a strongly emerging awareness in the private sector of the need to develop better approaches to address, and position for, the future.
2. The majority of the responses to this challenge in the private sector are organisational rather than technique- or fact-driven; the primary objective is to design an organisation that can learn, cope with uncertainty, position itself in a continuing flexible way for a range of possible futures.
3. Technology foresight techniques can play a valuable role in developing this capability. As in its application in the public sector, the value of the process is in most cases far greater than product outcomes.
4. Two major tools of technology foresight - Delphi surveys and scenario planning, have different characteristics and are most appropriate in different situations.

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Foresighting in the Thai Private Sector

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Deputy Secretary General, the Federation of Thai Industries
President of the SIKOR Group of Companies

The Federation of Thai Industries has conducted foresight exercises in three main areas: Energy and Clean Technology, New Materials from local resources and agro-Industry, and Communication/ Information Technology. Key topics considered by the Energy and Clean Technology Group include: the recycling of industrial water, treatment of hazardous solid waste, the use of alcohol and other alternative fuels for cleaner energy generation, energy conservation, and ASEAN environmental standards on air quality and vehicle emission standards. These topics are relevant to many different sectors of Thai industry, such as the textile industry, the food-processing industry, the automotive industry, and the plastics and chemicals industries. The second New Materials group covers four industries - petrochemicals, rubber, food-processing (again) and the ceramics industry. The petrochemicals industry has focused on new composite plastics, on recyclable and substitute materials, and on finding new niches. The rubber industry has been concerned with new applications and with synthetic materials, while the food-processing industry has been addressing issues of new product varieties, integrated processing, quality and nutrition, standards and hygiene. Lastly, the ceramics industry has been looking at developing new materials, engineering products and diversification and redundancy issues. The major concerns for the third group, Communication and Information Technology, have been human resource development, international trade and services. The relevant technologies here are connected with electronic data exchange, electronic money, service industry, information technology and technology for manufacturing.

The different foresight exercises have tended to use the methodology of scenario analysis. Such analysis has mostly been undertaken by ad hoc groups, comprised of members of the more active industrial clubs and invited experts, sometimes from other countries such as Japan and from special institutes.

While foresight is vital to the development and future success of Thai industries, it has been difficult to convince the private sector of its importance. Moreover, the lack of awareness of the relevance of foresight is compounded by the practical difficulties of carrying it out, in particular, inadequate human resources, information and time available.

Information Technology in Thailand in the year 2010 - a view from Delphi

Dr Pichet Durongkaveroj

Director, the Secretariat Office of the National IT Committee

In October 1993, the Science and Technology Development Program of the Thailand Development Research Institute Foundation published a study into the Role of Information Technology in the Information Society in the Year 2010. During this study, a Delphi survey was used to assist in the development of strategies to make effective use of IT so as to enhance productive efficiency, improve the quality of service delivery and raise the quality of life.

Before undertaking the Delphi process, the research team developed a vision of Thailand as an information society in the year 2010, where IT is used widely as the instrument for economic expansion and the enhancement of quality of life. The Delphi survey contained questions about the strategies required to bring Thailand to this position. Experts were also asked to state their opinion on when certain developments must be realized in order to reach this goal. The Delphi exercise surveyed the opinions of 16 experts, 8 Thai, 2 from the Netherlands, and 1 each from Canada, France, Japan, Korea, Singapore and the UK. Some small remuneration was provided to encourage participation in the survey and to prevent drop-out. The first set of questions was semi-structured, leaving some room for the experts to express their views. The responses were summarized using simple statistical descriptors such as median, mean and standard deviation, and returned to the experts, along with a new set of questions, developed from the previous list and the experts' suggestions. Again the responses were summarized and a third questionnaire was designed and distributed. The three rounds of correspondence were completed remarkably quickly, in about three months, owing to the excellent cooperation of the experts.

The experts categorized the strategies necessary to transform Thailand into an information society by the year 2010 as shown below:

most critical	critical
human resource development IT Infrastructure	market creation institution strengthening technology diffusion

most urgent	urgent	somewhat urgent
human resource development IT infrastructure	market creation institution strengthening	technology diffusion

The detailed strategies identified by the experts were then tested for robustness against possible scenarios for the future of Thailand. These four scenarios (later reduced to 3 since two were so similar) were based on the key issues of regional / international competition and political stability. 9 out of the 10 key initiatives identified by the experts were considered by the research team to be ‘very helpful’ under all three scenarios.

Annex I

The APEC Center for Technology Foresight Official Opening Ceremony and Seminar: Application of Technology Foresight

program

3 February 1998

Activity: Official Opening Ceremony and One-day Public Seminar
Venue: Siam City Hotel, 477 Si Ayuthaya Road, Bangkok 10400

Program:

08.00-08.45h	Registration
08.45-08.50h	Welcome *Dr Chatri Sripaipan* *Co-Director, APEC Center for Technology Foresight*
08.50-09.00h	Opening Ceremony *Presided over by H.E. Mr Yingpan Manasikarn* *Minister for Science, Technology and Environment* *Thailand*
09.00-09.10h	Opening Address **Impacts of Rapidly-Changing Technology on Social and Economic Development in APEC Region** *Mr Pithaya Pookaman* *Thai Ambassador-Designated to Bangladesh* *Ministry of Foreign Affairs, Thailand*
09.10-09.20h	Opening Remarks I *Professor Yongyuth Yuthavong* *Director, National Science and Technology Development Agency, Thailand*
09.20-09.30h	Opening Remarks II *Mr Jhong-Weon Shin* *Director (Program), APEC Secretariat, Singapore*
09.30-09.40h	Opening Remarks III *Professor Greg Tegart* *Director, APEC Center for Technology Foresight*

09.40-10.00h	Break
	Plenary Lectures Chair: Dr Chatri Sripaipan
10.00-10.40h	**I. Technology Foresight: Philosophy and Principles** *Professor Greg Tegart*
10.40-11.20h	**II. An Outline of the Sixth Technology Forecast Survey in Japan** *Mr Terutaka Kuwahara* *Director, Technology Forecast Research Team* *National Institute of Science and Technology Policy* *Japan*
11.20-12.00h	**III.Priority Setting for Science and Technology in the Public and Private Sectors in Canada.** *Mr Jacques Lyrette* *Vice-President (Technology and Industry Support)* *National Research Council, Canada*
12.00-13.20h	Lunch
	Plenary Lectures (continued) Chair: Dr Krissanapong Kirtikara Deputy Director National Electronics and Computer Technology Center
13.20-14.00h	**IV.Application of Technology Foresight to the Formulation of Science and Technology Policies: the Korean Experience.** *Dr Taeyoung Shin* *Policy Advisor* *Ministry of Science and Technology, Korea*
14.00-14.40h	**V. Technology Foresight Applications in the Private Sector** *Professor Ron Johnston* *Director, Australian Center for Innovation and International Competitiveness Limited* *University of Sydney, Australia*
14.40-15.00h	Break
	Panel Discussion: Technology Foresight Exercises Chair: Professor Ron Johnston
15.00-16.15h	**Foresighting in the Private Sector** *Mr Khemadhat Sukondhasingha* *Deputy Secretary-General of the Federation of Thai Industries, and CEO of Sikor Co. Ltd* **Information Technology in Thailand in 2010 - a view from 'Delphi'** *Dr Pichet Durongkaveroj* *Director, the Secretariat Office of the National IT Committee*
	followed by questions from the floor and discussion
16.15-16.25h	**Closing Remarks** *Professor Greg Tegart* *Director, APEC Center for Technology Foresight*

Annex II

Welcome Address at the Official Opening Ceremony of the APEC Center for Technology Foresight

Dr Chatri Sripaipan
Co-Director, APEC Center for Technology Foresight

Excellencies, Distinguished Guests, Ladies and Gentlemen

I have the pleasure to welcome you all to the Launching Ceremony of the APEC Center for Technology Foresight in Bangkok today.

We are here today to celebrate the efforts initiated by Professor Yongyuth Yuthavong more than two years ago when Thailand proposed the feasibility study for the establishment of the APEC Center for Technology Foresight to the First APEC Ministerial Meeting in Beijing.

In the course of the feasibility study, we went through four Industrial Science and Technology Working Group Meetings, an opinion survey, an APEC Symposium for Technology Foresight plus countless number of informal meetings and discussions. It was gratifying that all the way, we received strong support from member economies and the APEC Secretariat, in particular, financial support from the APEC Central Fund for the feasibility study and the establishment of the Center.

To witness the launching today, we have in this gathering 20 representatives from 12 APEC economies and 150 representatives from Thai public and private organizations. This will be followed by a public seminar throughout the day. The next three days will be devoted to a training workshop on technology foresight methodologies.

Now, I would like to invite His Excellency, Mr Yingpan Manasikarn, Minister for Science, Technology and Environment to deliver the opening address.

Annex III

Opening Address I

H.E. Mr Yingpan Manasikarn
Minister for Science, Technology and Environment, Thailand

Excellencies, Professors, Ladies and Gentlemen

I am delighted to preside over this Opening Ceremony of the APEC Center for Technology Foresight. My Ministry of Science, Technology and Environment oversees the work of the National Science and Technology Development Agency of Thailand, more simply called 'NSTDA'. NSTDA proposed a feasibility study for the establishment of this Center about three years ago, in 1995. Once endorsed by the first APEC Ministers' Conference on Regional Science and Technology Cooperation held in Beijing, NSTDA set to work to develop the concept of the Center. In this project, it was greatly assisted and supported by other APEC economies and also by international experts in the field of technology foresight from around the world. I am pleased to welcome many of these experts back to Bangkok today.

The APEC Center for Technology Foresight is the first APEC project of any kind to be established in Thailand. It reflects the emergence of Thailand as a newly-industrialized nation. Following recent economic problems, our success may have faltered but I believe that this is only temporary. We feel ready to meet the challenge of rebuilding our international competitiveness, with the welcome assistance of international agencies. In the longer term, the development of new technologies will be central to this goal. So let me assure this audience that Thailand remains committed to playing an active role in the development of the region. And we hope that this role can increase. The APEC Center for Technology Foresight is evidence of this commitment and we are proud to be its host.

Looking back at recent economic events, we can perhaps say that indications of the turmoil to come were there, if only we had known where to look. Of course foresight-looking ahead-can never be as perfect as hindsight-looking back. But the value of looking ahead and trying to plan for the future can never be underestimated. Had we conducted foresight exercises a few years back, we might have recognized that the bubble economy would one day burst. We could have prepared ourselves better.

For this reason, the new Center for Technology Foresight is especially welcome and timely. The Ministry of Science, Technology and Environment fully acknowledges the importance of Foresight. Some of our senior staff will be attending today's seminar and joining the training workshop, to learn more about these important techniques. And we are setting up a new Thai Foresight Unit to begin research into some of the crucial problems facing Thailand today.

On a regional level, I believe that the new Center can make a significant contribution to science and technology policy and planning in the region. Moreover, I expect the Center to enhance communication and cooperation between APEC member economies, which will benefit us all.

Annex IV

Opening Address II

"Impacts of Rapidly-Changing Technology on Social and Economic Development in APEC Region"

Mr Pithaya Pookaman
Thai Ambassador-designated to Bangladesh,
Ministry of Foreign Affairs

Distinguished Guests, Ladies and Gentlemen

It is a pleasure for me to address this international gathering on this auspicious occasion. First of all, let me congratulate the host organization on the successful launch of the APEC Technology Foresight Center which is to be followed by a public seminar and training workshop. I am confident that at the end of our activities, all participants will bring home with them a better understanding of the Center's objective and how to make the most use of it. I believe that the Center, if fully utilized, would make a great contribution to sustainable development of the APEC region as well as expand the scope of science and technological cooperation across the regions and multilateral groupings.

We have long realized how important technology is to our everyday lives. The impact of technology that has been improved each day affects the relationships between man to man as well as man to nature. Information technology and telecommunications systems have shrunk the world and brought people together while medical technology makes them live longer and therefore increases world population. Technology also plays a significant role in improving living standards, increasing educational opportunities and in strongly influencing public policy. More often than not it has developed so rapidly to the point that one could hardly imagine. For example, the development of cloning technology and, as I read in the Economist the other day, some university in Rome is working on 'teleportation'.

Besides the above, the improvement of transportation, telecommunications and productivity systems coupled with the need of people who demand more choices of products, leisure and facilities are major driving forces towards the expansion of economic growth and trade relations which eventually contributed to the formation of economic cooperation including APEC.

As the world's economies are growing more economically related and interdependent, it is crucial for an economy to maintain its technological progress so as to sustain economic growth and achieve greater productivity. Many developing member economies of APEC had developed their productivity as well as agrotechnology and enjoyed continuous economic growth for quite a long period of time before facing a sudden economic crisis. While the main cause may be found in the lack of preparedness of the financial sector and its regulation, one of the interrelating causes of the worsening economic situation derives from the lack of technological development and technology transfer in vital areas which would help sustain economic expansion amidst the economic turmoil. As we are living in the world of globalization, the crisis has proved borderless and affected not only the APEC region but the world at large. Therefore, it is clear the technological backwardness is unaffordable.

Even though we consider technology a good thing which should be incorporated in our lives, it generates both positive and negative impacts. The utilization of technological devices has no doubt caused the exploitation of natural resources, excess consumption of energy and waste produced in manufacturing and consumption processes which is the major cause for the rapid deterioration of the environment. Gas emissions from major industrial economies around the world that resulted in a serious greenhouse gases are a case in point. Besides posing a great risk to the environment, technology also influences human relations as it connects people as much as disconnects them. There are a number of cases in which people completely shut themselves from the world as they run everything through computers.

Realizing the pros and cons of technological utilization and the importance of improving technological capacity with the lowest possible risk, Thailand has included in her 8th National Economic and Social Development Plan the means of upgrading and utilizing technology in a sustainable manner. The plan promotes proper utilization of our limited natural resources, transfer of technological know-how and protection of the environment by means of promoting foreign investment, training exchange program, research cooperation among leading technological institutes, technological upgrading of enterprises and improvement of science and technological planning and management.

Aside from such an endeavor, Thailand along with other APEC member economies has cooperated in developing science and technology through the APEC Industrial Science and Technology Working Group which already possesses a large volume of cooperation in different sectors under way. The activities of the working group are geared towards the improvement of the flows of technological information and technology, researcher exchange and human resources development in the field of industrial science and technology, facilitation of joint research projects among APEC member economies, transparency of regulatory frameworks and contribution to sustainable development through environmentally friendly technologies.

Science and technological development in the APEC region is another important issue that was addressed by the economic leaders during the APEC Summit Meeting last November. In view of the growing role of science and technology in promoting economic growth and its close linkages to trade and investment flows, the Leaders directed Ministers to formulate an APEC Agenda for Science and Technology Industry Cooperation into the 21st century, and to present it to them at the next APEC Economic Leaders Meeting to be held in November 1998 in Kuala Lumper. I am certain that the agenda will lead to more consolidated and fruitful outcomes of science and technological cooperation in APEC.

The prospect of technological cooperation in the APEC region seemed even brighter when Russia was declared a new member of APEC along with Peru and Vietnam during the last APEC Summit Meeting since Russia's technological advancement is widely recognized as remarkable. During the meeting with the Prime Minister Chuan Leekpai early this January, the Ambassador of Russia pledged Russia's commitment to technological transfer and cooperation with Thailand and APEC. I believe the entry of Russia into APEC would mark a new era of APEC cooperation in the field of technology.

Considering the impact of technology on social and economic development in the Asia-Pacific region, APEC should strive for future cooperation as follows;

- Governments should take a leading role in coordinating, encouraging and promoting APEC technological cooperation at both bilateral and multilateral levels while enterprises should be the major player for economic growth and technical advancement and productivity.

- Cooperation among governments, universities, research institutes and private sectors should be further encouraged and widely publicized on a regular basis in order to gain support and participation.

- During the period of recovering from the economic turmoil besetting the Asian region, developing economies should give priority to developing their own technology base while keeping within acceptable proportions the dependence on the import of high technology. This is where the APEC Center of Technology Foresight should come into a focus. In view of our limited resources, the Center's work will help minimize the risk in the decision-making and planning process for future science and technology investment.

- Developing economies should give high priority to developing agro-technologies and agro-industrial technologies which would raise overall productivity and thereby contribute to food security and economic growth in the region.

- We must constantly upgrade our telecommunications systems and information technology devices to keep up with the rapidly changing world. The cost of such services should be reasonable and competitive.

- There should be a strong and immediate pursuit of environmental improvement and pollution control across the region. We all know that technologies have caused a rapid deterioration of environment but it is technology that we have to help develop to mitigate the problem.

The road to the goals might be long, painful, unarguably costly and require a strong will and cooperation from the smallest to the largest sectors in the society, but we are bound to make it a success. And the result is worth achieving. I am confident that the opening of the APEC Technology Foresight Center will make a substantive contribution towards our goals. Lastly, I wish you all a productive and fruitful meeting and a successful operation of the Center in the future.

Thank you.

Annex V

Opening Remark I

Professor Yongyuth Yuthavong
Director, National Science and Technology Development Agency, Thailand

Excellencies, Distinguished guests, Ladies and Gentlemen

Today is a very special occasion and a remarkable day for our gathering here. We have arrived here from many different places. Some of you may come from outside Bangkok and certainly a number of you come from outside Thailand. I would like to express my gratitude to you all for your presence here to assist, to support, and to witness the launch of the APEC Center for Technology Foresight which is the first APEC Center located in Thailand. Also, I very much appreciate your interest in participating in the first APEC Center's activities: the one-day seminar today and the following three-day workshop.

I believe we truly realize that to move from the initiation of a project to its reality requires great effort and determination, and the cooperation of many people working together. Thanks to more than two years of great effort, commitment and vision of a group of people in and outside Thailand, the establishment of the APEC Center becomes reality today. In this regard, I would like to request a few minutes of your time to address the past work that led to the launch of the APEC Center today:

- The idea for establishing an APEC Center for Technology Foresight arose in 1995. A proposal for a feasibility study for such establishment was submitted to the first APEC Ministers' Conference in Beijing, by the National Science and Technology Development Agency through the Ministry of Science, Technology and Environment of Thailand. The proposal was endorsed in that meeting.

- The feasibility study was then carried out for over one year by a Thai working group who consulted with experts both within and outside APEC. In this period of study, seminars, workshops and meetings were arranged, to exchange and disseminate knowledge. A few brainstorming sessions were also convened. Subsequently, a survey of opinions on possible topics for research study by the APEC Center was conducted.

- The feasibility study was completed with the organization of an APEC Symposium on Technology Foresight held in Chiang Mai last June. The Symposium was successful and very productive. Thirty-two delegates from 11 APEC member economies, not including Thailand, participated in the Symposium. They shared their expertise and showed their support for the establishment of the APEC Center.

Throughout this period I have been describing, I witnessed close cooperation between Thai and international players and I was extremely impressed with it. I therefore salute the efforts of those who built and bridged this cooperation. The launching event today could not have happened without this. The cooperation is also essential to the future success of the Center. In this regard, I would particularly stress the importance of cooperation among all APEC member economies and I would like to encourage involvement of all economies.

We all are aware that although technology foresight has been used for decades in some major countries, but it is a new approach to many countries or economies including Thailand. I can say that when we were working on the feasibility study, we were also exploring this new approach for ourselves. As our understanding of technology foresight developed, we came to appreciate its importance to science and technology development even more fully. Successful development of science and technology relies on effective science and technology planning, and technology foresight can be a very effective tool for policy-making and strategic planning.

At this moment I would like to pledge publicly my gratitude to the following individuals and institutions:

- I would like to acknowledge the support of the APEC Secretariat and the APEC Industrial Science and Technology Working Group.

- I would like to acknowledge the Ministry of Science, Technology and Environment and the Ministry of Foreign Affairs of Thailand for their coordination and cooperation.

- I would like to acknowledge international friends of NSTDA for their support, assistance and consultation, namely - Professor Greg Tegart and Professor Ron Johnston from Australia; Mr Terutaka Kuwahara from Japan; Dr Taeyoung Shin from Korea; Dr Rogelio Panlasigui from the Philippines; Dr Arthur Carty, Mr Jacques Lyrette, and Dr Sadiq Hasnain from Canada; Mr Jhong-Weon Shin of the APEC Secretariat; as well as Dr Joe Anderson and Dr Luke Gorghiou from UK; and Dr John Richards of the British Council in Thailand.

- I would also like to pledge my appreciation to my colleagues for their hard-work and their dedication to the work they have done.

- I must also thank, very much, all the other persons in and outside Thailand who helped and supported our work - I cannot spell out all their names today.

Excellencies, Ladies and Gentlemen

As you know, the APEC Center for Technology Foresight starts its operation today. NSTDA has committed itself to running the Center actively. I would like to emphasize how much we look forward to, and depend upon, the involvement, contribution, cooperation and support of all the APEC member economies as well as from other countries, organizations and institutions outside the APEC region. To make the world a place worth living in, we must look into our long-term future and learn how to live together and work together.

Lastly, may I express my thanks to the organizers of this Opening Ceremony and Public Seminar today, and the workshop that begins tomorrow, and wish you all an enjoyable and stimulating day.

Thank you.

Annex VI

Opening Remark II

Mr Jhong-Weon Shin
Director (Program), APEC Secretariat, Singapore

Ladies and Gentlemen

It is an honor indeed to join you to observe the opening of the APEC Centre for Technology Foresight. It is a great pleasure to extend thanks and congratulations to our friends involved in the creation of this Centre, especially the experts in the National Science and Technology Development Agency of the Kingdom of Thailand.

They deserve thanks and congratulations, which I am extending to them on behalf of our colleagues in the APEC circle working on industrial science and technology and the APEC Secretariat in Singapore.

Establishment of this Centre has been a challenging but rewarding job. It demanded time and energy of policy makers and experts in this area.

Thailand's idea on a centre for technology foresight was accepted at the 1st APEC Ministers' Conference on Regional Science and Technology Cooperation held in Beijing, China, in October 1995.

Experts have elaborated this idea since then, and received wide support from the APEC fora, including Industrial Science and Technology Working Group. APEC also decided to contribute financial support to help institute this Centre.

This Centre is relevant and timely, especially in view of the current APEC programmes. Closer cooperation on APEC level in this field of technology foresight, I believe, will help to bring about substantial outcomes to guide APEC activities in the area of industrial science and technology.

Please allow me a few moments to make four observations why this Centre is relevant and timely.

Firstly, technology. What is technology to us?

I must say that technology has been a driving force in the development of human history, hence our life conditions now. Technology advances including the printing press, the compass, the steam engine, the telephone and the computer have laid the foundation of our current life. Thus technology is about innovation and capacity building towards development of our history including economic growth.

APEC is aimed at attaining sustainable growth and equitable development in the Asia-Pacific, and APEC has given science and technology a high place in its agenda.

Cooperation in science and technology, hence action plan of the IST Working Group, has been included from the beginning as one of the APEC programmes. And in 1996 in Manila, APEC Ministers and Leaders listed 'Harnessing Technology for the Future (HTF)' as one of six priority themes of economic and technical cooperation in APEC. Again, last year in Vancouver, this 'Harnessing Technology for the Future' was selected as one of the main themes for 1998 by APEC member economies with the leadership of Malaysia, who is host economy of APEC Ministers' and Leaders' meetings this year.

Secondly, what is technology foresight?

Foresight is an act of looking forward to the future. Foresight implies prediction, and it requires prudence, exercise of reason and wisdom. Thus, technology foresight is a structured exercise to identify and promote technologies that are likely to emerge in the future with great potential to yield economic and social benefits.

According to the experts, this exercise of technology foresight is necessary for the reasons, which include:

1) Technology development depends on the development of science, which is not always predictable.
2) Technology may not be put into practical use even when a technology is possible for a variety of non-technical reasons.
3) Resources are limited and need to be managed with the best care and efficiency.

Thus, technology foresight is essential. This exercise may help to recognize technology and market discontinuities, create new competencies, differentiate products and services for the maximum benefits.

Technology foresight can be instrumental to our efforts to bridge the gap in technology and economic development between the developed world and the developing countries. These efforts, I hope, will help to pull out of the difficulties facing us now in this part of the world.

Thirdly, why do we need a centre for technology foresight?

Again according to the experts, technology foresight has been developed and applied since the 1950s in the developed countries, while some industrializing economies have just started this exercise. There arises the question of different approaches and methodologies for this exercise, reflecting the diversity of the world in economic, social, cultural and other aspects.

In this context there arises a need to provide a focal point for technology foresight on a multi-economy basis. Different approaches and different methodologies need to be consolidated in the APEC context, not least because APEC has a vision to achieve an APEC community which was adopted by our Leaders in Seattle in 1993.

Fourthly, what do we expect from the APEC Centre for Technology Foresight?

The APEC region comprises a vast geographical distance and great diversity in social, cultural and economic development. This means that technology foresight in APEC has a potential for a large scope. The issue here is that we in APEC have limited resources, and we need to put these limited resources in other important areas as well.

I understand that a research has been conducted on the scope of its work in the process of feasibility studies for this Centre. I am sure that the mandate of the Centre will accommodate our needs in APEC for the benefit of our future.

In this connection, I wish to draw your attention to one of recent developments in APEC. Our Leaders, in their Declaration at Vancouver in November 1997, directed their Ministers to formulate an APEC Agenda for Science and Technology Industry Cooperation into the 21st Century.

This direction mirrors their recognition of the growing role of science and technology in improving economic growth, and its close linkage of technology to trade and investment flows. This agenda will be developed through consultations among APEC member economies at various fora. I believe this Centre will also lend its hand to this end.

Ladies and Gentlemen

This Centre testifies to the strong commitment to an active role in APEC of the Thai Government, and I wish to express thanks once again, on behalf of my colleagues in the APEC circle, to the Thai Government and Thai friends, who have worked hard for this Centre.

I wish to join you, wishing every success to this event for opening the APEC Centre for Technology Foresight, and to public seminar and training workshop scheduled hereafter. I hope you will all find today and next few days rewarding to you and APEC as well.

I wish again the Centre a greater success with your more contribution and involvement with time passing.

Thank you for your attention.

Annex VII

Opening Remark III

Professor Greg Tegart
Director, APEC Center for Technology Foresight

Excellencies, Distinguished Guests, Ladies and Gentlemen

This occasion marks the culmination of some 2 years of planning and hard work in developing the Center from a concept to a reality. The successful creation of such a project, like other major human achievements, often owes much or even everything to a single individual who by some mixture of conviction, persuasion and competence succeeds in securing the necessary resources, wins sufficient time and overcomes all the obstacles. The role of such champions is significant in dealing with governments in situations where personal prestige, diplomatic talent and personal or professional links can play a decisive role.

In the case of the APEC Center for Technology Foresight, the champion has clearly been Professor Yongyuth Yuthavong who has in his quiet and unassuming way driven the project along by inspiring his NSTDA colleagues, convincing his government and his Board to finance it and persuading his international colleagues to support it. Without him the project would never have been realized.

I deeply appreciate the honor of being invited to be the inaugural Director of the Center and, together with my distinguished Co-Director, Dr Chatri Sripaipan, will take up the challenge to make the Center a significant player in the S&T development of the APEC economies. While numerous countries have been developing and applying foresight techniques on a national scale for two decades or more, the concept of applying them on a regional basis has only been attempted in the last year or so in Europe through the Center for Prospective Technologies, formerly in Triestte and now in Seville. Co-operation among the European countries in terms of S&T and environmental issues has been developing strongly over the past decades and the Framework Program is now well-developed and constitutes a significant fraction of the S&T activity and expenditure in major projects which cannot be funded by one country alone, eg accelerators, reactors, space activities, and foresight techniques have been used as an integral part of the development of such projects on a multi-nation basis. Even so, application to broader issues of environment, transport etc is still at an early stage. By contrast, the APEC economies are much more diverse in their levels of technological development and economic progress and apart from the ASEAN group of economies, there is little or no history of co-operation in S&T and environmental projects on a multi-economy basis. The situation is improving rapidly as a result of the activities of the APEC Industrial Science and Technology Working Group which is developing a number of co-operative projects drawing together the APEC economies. Other Working Groups in energy and human resource development are also actively building up regional co-operation.

However, APEC at its present stage of development does not have the structure nor the financial resources of the European Community and co-operation is highly dependent on the contributions of member economies. It is significant therefore that Thailand has chosen to use its limited resources to back the development of this Center as a contribution to the future developments of the APEC economies.

Science and technology are vital to our societies in terms of social, economic and environmental development. They lead to wealth creation and improvement in the quality of life, as dramatically demonstrated in a number of the APEC economies over the past decade. Successful exploitation of technology has become critical to achieving economic competitiveness. The fact that economic growth has faltered in a number of APEC economies as a result of factors other than exploitation of S&T should not distract us from their achievements!

The value of foresight is that it provides a structured opportunity to look ahead and to consider the role of S&T that may be required in the future. A useful definition of foresight is: 'A process by which one comes to a fuller understanding of the forces shaping the long-term future which should be taken into account in policy formulation, planning and decision making. Foresight involves qualitative and quantitative means for monitoring clues and indicators of evolving trends and developments and is best and most useful when linked directly to the analysis of policy implications'.

This definition has several implications:

(a) foresight is a process rather than a set of techniques and involves consultation and interaction between the scientific and technological community, users of their outputs and policy-makers

(b) foresight is concerned not so much to predict the details and timing of specific developments as to outline the range of possible futures which emerge from alternative sets of assumptions about emerging trends and opportunities

(c) the foresight process must be transparent to allow the underlying assumptions, analytical framework and data inputs to be subject to external scrutiny. Such openness also allows non-conformist views to be given equal weighting with conventional ones and to identify emerging paradigms.

(d)foresight is neither simple or unproblematic and provides an input to the decision-making process but does not provide a definitive solution.

The challenge for us in the Center is to convince our colleagues in the APEC economies of the value of technology foresight and thus to contribute to the continued creation of wealth and enhancement of the quality of life through sustainable development of our natural and human resources.

Annex VIII

List of Participants in the public Seminar

APEC Symposium on Technology Foresight
Bangkok, Thailand
February 1998

AUSTRALIA

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Annex IX

Summary Record of the first APEC Technology Foresight Workshop Using Technology Foresight

The first APEC Technology Foresight workshop was held at the National Science and Technology Development Agency, Bangkok, 4-6 February 1998. The workshop was attended by 30 participants from 6 different APEC member economies (China, Chinese Taipei, Indonesia, Malaysia, Singapore and Thailand), with the four expert facilitators representing a further 3 APEC members (Australia, Japan and Korea). The workshop was preceded by a full-day public seminar at the Siam City Hotel, Bangkok, Thailand, which provided an introduction to technology foresight. The workshop was opened by Dr Chatri Sripaipan, Co-Director of the APEC Center for Technology Foresight.

List of Facilitators

Professor Greg Tegart	Director, APEC Center for Technology Foresight also: Honorary Professor of Science Policy at the University of Canberra, Australia, and Distinguished Visiting Professor at Victoria University of Technology, Melbourne, Australia
Professor Ron Johnston	Executive Director, Australian Center for Innovation and International Competitiveness Limited (ACIIC), University of Sydney, Australia
Dr Taeyoung Shin	Policy Advisor, Ministry of Science and Technology, and Senior Fellow, Science and Technology Policy Institute, Korea
Mr Terutaka Kuwahara	Director, Technology Forecast Research Team, National Institute of Science and Technology Policy, Japan

Workshop Program

During the opening session, participants introduced themselves and their interest in technology foresight. The first day program comprised a series of lectures, with opportunities for participants to ask questions and to check their understanding. Professor Tegart began with an overview of the foresight process, followed by Mr Kuwahara's description of how to select foresight topics. Professor Johnston went on to explain about how to identify critical technologies and the key social and economic trends that may affect them. In the afternoon session, Dr Shin provided a comprehensive survey of technology foresight methodologies. Finally, Mr Kuwahara explained some of the ways in which foresight findings have been prioritized and implemented in Japan.

Days 2 and 3 of the workshop provided 'hands-on' experience of two key foresight techniques, Delphi and Scenario-based Planning. The program was extremely interactive, with small group work, followed up with larger group discussions. All the facilitators were available to advise and encourage participants throughout the program. The workshop used topics which the APEC Center for Technology Foresight hopes to explore in future research. These were the topic of *Water Supply and Management* during the Delphi training and the topic of *The Use of Technology for Learning and Culture* during the Scenarios training.

Workshop Evaluation

Evaluation Forms were distributed to the 30 participants and 26 were returned. The rating results, displayed in full in the table below, show that the workshop was extremely successful.

Absolute Numbers / ***Percentages (of 26)***

		Very good		good		fair		poor		no answer	
I	**Program of the workshop**										
	1.1 Contents of the program	10	***38***	15	***38***	1	***4***	-		-	
	1.2 Appropriateness of the program	8	***31***	15	***58***	3	***12***	-		-	
	1.3 Time-schedule of the program	2	***8***	20	***77***	4	***15***	-		-	
	1.4 Materials provided in the workshop	5	***19***	14	***54***	6	***23***	1	***4***	-	
	1.5 Your opportunity to participate in the group discussion or to provide opinions	7	***27***	15	***58***	3	***12***	-		1	***4***
	1.6 Information/knowledge you obtained from the workshop	7	***27***	16	***62***	3	***12***	-		-	
	1.7 Expected future utilization of the information/knowledge obtained from the workshop	5	***19***	18	***69***	2	***8***	-		1	***4***
II	**Communication**										
	2.1 Communication between you and the facilitators during the workshop	9	***35***	12	***46***	5	***19***	-		-	
	2.2 Communication between you and the organizers	10	***38***	13	***50***	2	***8***	-		1	***4***
III	**Others**										
	3.1 Environment	15	***58***	10	***38***	1	***4***	-		-	
	3.2 Meals	10	***38***	13	***50***	2	***8***	1	***4***	-	
	3.3 Other facilities	9	***35***	12	***46***	2	***8***	-		3	***12***

Participants also offered the following suggestions for future workshops, and future activities of the Center.

1) Suggested Future Workshop Themes:

- comparisons of every country's experiences of Delphi and Scenario methods
- technology and development
- creative thinking
- innovation practices
- experiences in implementing technology foresight / application of technology foresight results-successes and failures
- science and technology in 2020 / technology for Thailand and APEC in 2015
- technology foresight for Small and Medium Enterprises
- science education
- technology trade in APEC
- environmental management
- other foresight methods (besides Delphi and Scenario), such as relevance trees and cross-matrix index
- deeper training on scenarios-another 2 days

2) Suggested Future Center Activities

- consultation for agencies, on request
- develop and publish guidelines about the philosophy, concept and methodologies
- technical support for countries undertaking Delphi programs
- support for individual personnel exchanges between key experts to help technology foresight projects in specific countries, for example a Japanese expert to visit and assist China
- exchange of information about technology foresight, through e-mail and web site / periodic brochure / newsletter, including the progress of foresight exercises within APEC and the progress of the Center itself
- establish a Foresight Forum-a periodic meeting to exchange ideas and practices
- seminar by Professor Ben Martin of the Science Policy Research Unit, University of Sussex, UK
- annual recall of Thai participants to exercise foresight together and foresight future technology
- annual public seminar
- regular joint conference of the APEC Center with APEC member governments (say, bi-annual)

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Malaysia	
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Dr Porpan Vachajitpan	Advisor to the Deputy Minister, Ministry of Science, Technology and Environment
Dr Prakin Suchaxaya	Assistant President, Chiang Mai University
Dr Prasong Praneetpolgrang	Director MS Program (IT), Sripatum University
Mr Pun-Arj Chairatana	Policy Analyst / TGIST Coordinator, NSTDA
Dr Saran Poshyachinda	Researcher, MTEC, NSTDA
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Ms Surat Chumjit	Policy and Planning Analyst, King Mongkut Institute of Technology, Thonburi
Mr Theera Poomsanoh	Managing Director, C. I. Group Company Limited
Ms Thippaya Tanghongs	Assistant Director, Technology and Environment Planning Division, National Economic and Social Development Board
Ms Usapan Swasdio	Policy and Planning Analyst, NECTEC, NSTDA
Ms Uthaiwan Grudloyma	RD&E Analyst, BIOTEC, NSTDA
Dr Yada Mukdapitak	Chief of Policy Section, Office of Policy and Planning, Ministry of Science, Technology and Environment

Annex X

“Technology in Harmony with Culture and Environment”

by
Professor Sippanondha Ketudat
Chairman, National Economic and Social Development Board, Thailand

Excellencies,

Mr Chairman, Members of the International Advisory Board and Members of the Steering Committee of the APEC Center for Technology Foresight,
Mr Permanent Secretary of the Ministry of Science, Technology and Environment of the Royal Thai Government,
Mr Representative of the APEC Secretariat,
Mr Director of the National Science and Technology Development Agency, Thailand
Mr Director of the APEC Center for Technology Foresight,
Distinguished Workshop Participants,
Honorable Guests,
Ladies and Gentlemen,

It is indeed a great pleasure and an honor for me to be invited to address such a distinguished gathering of key players in science and technology of the APEC economies today. May I thank and congratulate all those who have contributed their efforts to make the APEC Center for Technology Foresight a reality.

With a common will and commitment as shown in the participation of the first series of events taking place beginning all day today and continuing on during the next few days, I am certain that the APEC Center for Technology Foresight will be able to carry out the task assigned in accordance with objectives to face the challenge of the future.

Let me take fifteen minutes of your precious time briefly to outline my thoughts on technology foresight and technology in harmony with culture and environment by raising four questions and answer them briefly from my own perspective.

1. Why technology foresight?

Ever since we inhabited the world, human beings have always tried to find out the relations between ourselves and the surrounding environment. What is going to happen to us in the future has often been our central concern. The Lord Buddha stated almost 2,600 years ago and I quote:

"Prepare as best you can for the future, and do not let your arrangements constrain you, when the time for action arrives.."

Or stated in a very simple language, as I was given to understand that one of the most recent foresight projects in APEC recognized that a society without planning is like a "possum caught in the glare". A society exposed to the glare of the on-coming future, without planning and preparation, is vulnerable indeed.

Let me take just one more example of Thailand as we are caught up in the glare today. Had we been prepared to take up the challenge of adverse effects of globalization with appropriate information technology on the liberalization of financial institutions, and the speed of light instruction on the Thai Baht currency speculation from across the world, Thailand would not have faced as great a financial and economic crisis as we are facing today. Unpreparedness is indeed very costly, an extremely expensive lesson not only for Thailand but for all the other inter-related economies also.

As we see from this real and painful live example, technology has become a central feature of all modern societies and its importance is likely to increase.

We must have foresight on technology, its implications, opportunities and the threats associated therefrom, so that consequently we can choose technology appropriate to fit our culture. We must not only have such foresight but we must also prepare ourselves to tackle them.

2. Why a Multilateral APEC Center?

By now, most of us would agree that foresight and planning are necessary at institutional, company and national levels. But why is it necessary at the multi-country level? First, the Center can help to spread technology foresight expertise across the APEC region, allowing economies new to this process to learn from those with more experience. The recent economic turmoil shows that the advanced countries of APEC cannot afford to ignore those still developing. The global interconnection of markets mean that no economy is completely isolated from others. At the moment, the richer economies in APEC are concerned that economies at the sharp end of the economic crisis will be unable to import their products, while their own domestic markets will be flooded by products made so much cheaper than their locally-made ones, by falling currency exchange rates. Thus it is in the interests of advanced economies to assist and cooperate with the rest. Moreover, developments in the techniques and practices of technology foresighting will surely result from the expansion of its use to a wider range of economies - which will benefit even those economies with previous experience of foresighting.

However, the Center aims not just assist economies with their own foresight efforts. The Center also plans to conduct research at a multi-country level. Technology may be able to contribute to issues which cross national boundaries - from air pollution, to chicken virus, to electronic information distribution. ...In doing this, the APEC Center will be breaking new ground. Cross-country foresighting has not yet been tried, and this experiment is being watched with great interest by experts in science policy and planning all over the world.

3. Why Thailand?

Some comments on why this Center has been located in Thailand. This is the first APEC project of any kind to be located in Thailand. It is a reflection of past success in developing our country, and of our commitment to renew our success in the future, with sound economic management, assisted by international agencies. Thailand is able and willing to play an active role in APEC, and in other international fora. As a newly industrializing country, Thailand can provide a bridge between the advanced countries of APEC and those that are still much less industrialized. We have the infrastructure to support the Center, for example in information technology and telecommunications facilities, to international standard. Equally important, we have the will to make the Center succeed. With the commitment of the National Science and Technology Development Agency of Thailand - which hosts the Center, and the support of all the APEC member economies, the APEC Secretariat and the APEC IST Working Group, I am sure that the Center will make an important contribution to science policy and planning throughout the APEC region.

4. Foresight and Choice: Do We Have Any Choices?

I have raised this question several times since my childhood. When I was a child, I was amazed at days and nights, the sun and the moon, the planets and the stars, the past and the future. My few sentences answer are: the choice and your power to choose depend on the roots of your culture and your own self; how strong you are in relation to external contexts and pressures.

As for my own, I have faith in harmony not dichotomy. My belief and experience tell me that when a new idea or a new external materialistic body enters into a peaceful with stable equilibrium body, a slight perturbation may cause the body to move towards a new equilibrium state if that perturbation is gradual and not much different from the original peaceful and stable body. A quantum jump or an explosion or an implosion is also possible when the original body is not peaceful and / or the body is at a non-stable equilibrium position.

Excellencies, Ladies and Gentlemen

I leave this question for you to answer for yourself. Depending on your philosophy, your faith and your belief, the choice is yours.

One final comment, although there are myriads of positive impacts coming from information technology upon Thailand, I have used as an example, the negative impact of unpreparedness to take up the challenge of liberalization of financial institutions in information technology in order to demonstrate the other side of the coin of technology.

This negative side of the coin may be a lesson for all of us and may be summed up in this way. In any economy, the financial sector ('the unreal sector') has to be in proper step with the productive sector ('the real sector'). In the present world, with the utilization of information (bits and digits) is much more than the goods and services (atoms) transactions. Furthermore, financial transactions are as fast as the speed of light. Unless people and societies understand this imbalance, the 'bubble' and the implosion of economies may be with us for a long, long time.

Excellencies, Ladies and Gentlemen

My own conclusion is: we have a choice on technology. We must prepare ourselves adequately and my choice is technology in harmony with culture and the environment.

Thank you.

Annex XI

Members of the Steering Committee, International Advisory Board and Staff team

Steering Committee

Advisor:	Mr Kasem Snidvongs Na Ayuthaya Permanent Secretary of the Ministry of Science, Technology and Environment, Thailand
Chairman:	Professor Yongyuth Yuthavong Director of NSTDA, Thailand
Members:	Dr Suvit Vibulsresth Deputy Permanent Secretary of the Ministry of Science, Technology and Environment, Thailand
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	Associate Professor Songkram Luangtongkum Deputy Permanent Secretary of the Ministry of University Affairs, Thailand
	Deputy Permanent Secretary of the Ministry of Industry, Thailand or a representative
	Director-General of the Department of Economic Affairs, Ministry of Foreign Affairs, Thailand or a representative
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	Dr Krissanapong Kirtikara Deputy Director, NECTEC, NSTDA, Thailand
Secretary:	Professor Greg Tegart Director of the APEC Center for Technology Foresight
Assistant Secretary:	Dr Chatri Sripaipan Co-Director of the APEC Center for Technology Foresight

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Director of NSTDA, Thailand

Members: Professor Sipphanondha Ketudat
Chairman of the Executive Board, Office of the National Economic and Social Development Board of Thailand

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Policy Advisor, Ministry of Science and Technology and Senior Fellow, Science and Technology Policy Institute, Korea

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Application of Technology Foresight

PUBLIC INFORMATION DEPARTMENT, NSTDA 1998

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