Results of the Sixth Technology Forecast Survey

- Future Technology in Japan Toward The Year 2025 -

(NISTEP Report No. 52)

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1. Objectives

The Science and Technology Agency has been conducting technology forecast surveys since 1971, generally every five years, to ascertain the future direction of technology development in Japan from a long-term viewpoint. This report covers the 6th survey, which was undertaken in the FY 1995-1996 period, using funds made available from the Science and Technology Promotion and Coordination Budget.

2. Survey Method

(1) Implementation structure

For the survey, the National Institute of Science and Technology Policy (NISTEP) established a technology forecast committee to examine the overall survey plan and implementation guidelines, and the Institute for Future Technology (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 ("resources and energy" and "environment" handled together by a single subcommittee). NISTEP also undertook analyses covering all fields and other tasks.

(2) Forecast period

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

(3) Survey fields (Number of topics)

1) Materials and processing	(109)	8) Environment	(39)
2) Electronics	(74)	9) Agriculture, forestry and fisheries	(84)
3) Information	(79)	10) Production and machinery	(71)
4) Life science	(94)	11) Urbanization and construction	(73)
5) Space	(51)	12) Communication	(78)
6) Marine science and earth science	(74)	13) Transportation	(60)
7) Resources and energy	(88)	14) Health, medical care and welfare	(98)
		Total	(1072)

Of the total 1072 topics, 380 were identical to those included in the previous survey, 233 were modified, and 459 were newly introduced.

(4) Survey technique

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

(5) Study items

1. Degree of importance to Japan	4. Current leading countries etc.
2. Expected effect	5. Effective measures the government should adopt in Japan
3. Forecasted realization time	6. Potential problems in Japan

(6) Questionnaire rounds

Potential respondents were selected based on recommendations by members of each subcommittee and other methods, with the first questionnaire sent only to those who consented to a prior request for participation. Questionnaire forms were distributed in the manner shown below.

Round	Mailing period	Forms distributed	Forms recovered	Recovery rate
1st questionnaire	August 1996	4,868	4,220	87%
2nd questionnaire	December 1996	4,196	3,586	85%

The backgrounds of the respondents to the second questionnaire were as follows:

Age group		Occupation	
20s	1%	Company employee	36%
30s	8%	University staff	37%
40s	36%	Public servant	15%
50s	41%	Association employee	10%
60s	13%	Other	2%
70s and over	1%		

3. Survey Results (Outline)

(1) Fields with high degree of importance scores

Figure 1 gives an overall picture with individual field-by-field scores. From this, it can be seen that perceived importance is high in the environment, electronics and life science fields.

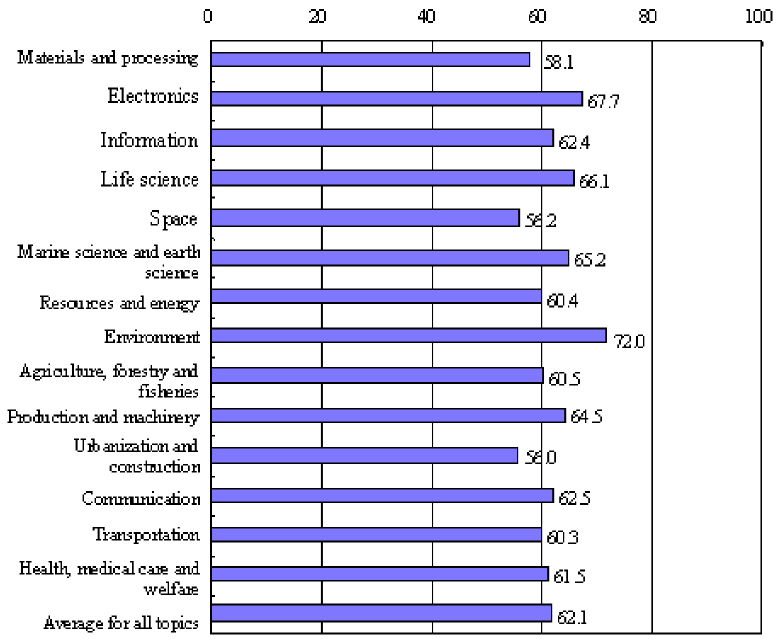

Figure 1 Importance Index by field

The top 100 degree of importance index topics in the 6th survey and their 5th survey counterparts were classified into the following five categories:

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

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

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

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

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

The results are shown in the table below.

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

Notably, the number of information-related technologies increased dramatically, while that of life-related technologies decreased. The number of new energy technologies also rose.

1) With environment-related technologies, the number of topics relating to "recycling", such as the greater acceptance of product design concepts that facilitate recycling and the practical use of plastic recycling technologies, has risen to nine (four in the fifth survey). On the other hand, topics relating to the "global environment", such as the practical use of CO_2 fixing technology and fluorocarbon and halon substitutes, fell to seven (13 in the fifth survey), indicating that there has been a shift in perceived importance with regard to environmental technologies towards a more concrete down-to-earth approach.

2) With information-related technologies, the number of "network" system topics, such as practical use of a high-security next-generation Internet and widespread use of networks that provide better privacy protection and confidentiality of information, jumped to 12 (two in the fifth survey), with that of topics relating to "semiconductor etc.", such as practical use of 256-gigabit memory chips and practical use of mass-production processing technology for 10 nm patterns, also rising to 11 (six in the fifth survey). Factors that are thought to lie behind these increases include the rapid popularization of the Internet throughout the world, including Japan, over the five intervening years between the last two surveys and the associated increase in awareness of the need for service diversification and security improvements.

3) With life-related technologies, there has been little change in the number of topics relating to "cancer", such as practical use of means of preventing metastasis, falling slightly to nine (10 in the fifth survey), while that of topics relating to the "brain", such as the treatment of Alzheimer's disease, fell sharply to one (eight in the fifth survey). Topics relating to the treatment of various diseases, such as arteriosclerosis, also experienced a fall.

In light of the fact that the average importance index score for the life science field as a whole remains high in this survey, the relatively fewer number of high-ranking topics from the life science field does not necessarily mean that there has been a decline in the perceived importance of this field. Rather, it is thought to be largely attributable to the exceptionally high level of importance that information-related technologies received this time.

4) With disaster-related technologies, the number of topics relating to "earthquakes" rose to eight (four in the fifth survey), pushing up the overall number of topics in this category.

5) With new energy technologies, topics relating to "solar cells" rose to four (two in the fifth survey), and all are ranked within the top ten or thereabouts. There was little change in the number of topics relating to other technologies, such as nuclear power.

Note: Degree of importance index devising method

For all topics, the degree of importance score was calculated in accordance with the formula shown below. Namely, survey participants were asked to specify the importance of each topic by choosing their answers from "high", "medium", "low" and "unnecessary", with the answers first quantified by allocating them weighting values of 100, 50, 25 and 0 and then totaled and averaged. According to this formula, therefore, the index is 100 if all respondents indicate "high" degree of importance and 0 if all respondents think the technology is "unnecessary".

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

(2) Technologies with high expected effect

For each topic, survey participants were asked to specify the expected effect(s) of the technology concerned by choosing one or more answers from the following list:

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 diseases, improve-ment 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.

Figure 2 shows the percentage response shares of the above choices as averaged over each field. Fields expected to make a great contribution to socioeconomic development include electronics, communication, materials & processing, production & machinery, and information, while those expected to make a great contribution to the resolution of global problems include the environment, resources & energy, and agriculture, forestry & fisheries. As for response to people's needs, expectations are high for health, medical care & welfare, information, urbanization & construction, and other fields.

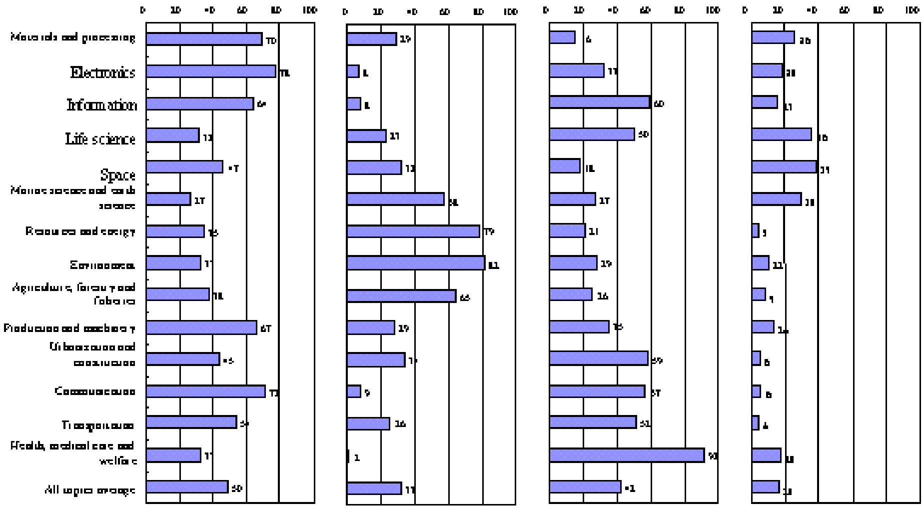

Figure 2 Trends in expected effect (by field)

≪Examples of topics expected to have great effects≫

"Contribution to socioeconomic development"

- (Electronics) Widespread use of a portable multimedia wireless terminal which can be used throughout the world
- (Communication) Practical use of a highly secure next-generation Internet that allows the transmission of real-time information

"Resolution of global-scale problems"

- (Environment) Introduction of environment tax geared towards global environmental conservation
- (Resources) Practical use of technologies capable of separating useful metals from scrap cars etc. to a purity level of more than 99%

"Response to people's needs"

- (Health) Widespread use of scientific guidelines for adult-disease-prevention lifestyles (nutrition, rest and exercise)
- (Information) Practical use of robots which provide medical care support in homes, hospitals, etc.

"Expansion of human intellectual resources"

- (Space) Return of samples from other planets
- (Life science) Elucidation of the molecular mechanism of life creation

(3) Trends in forecasted realization time

Figure 3 shows the distribution of forecasted realization times of all 1,072 topics.

- Fields that have a large number of topics with a relatively early forecasted realization time: Information and communication
- Fields that have a large number of topics with a relatively late forecasted realization time: Resources & energy and life science
- Although numbers are small, some topics are forecasted to be realized by 2005, mainly in the fields of

information and communication.

- More than a third of all topics are forecasted to be realized in each of the two 5-year periods of 2006-2010 and 2011-2015, and as many as three quarters are forecasted to be realized in the combined 10-year period.
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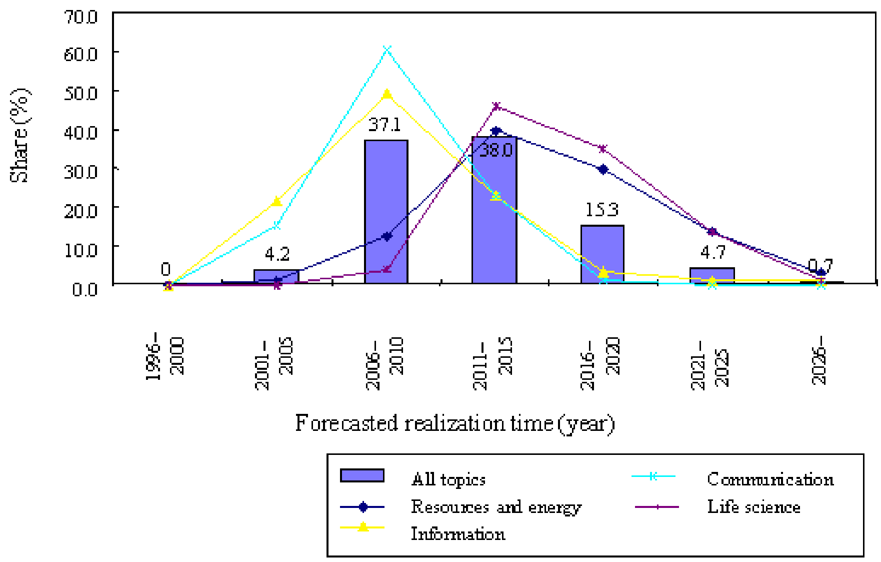

Figure 3 Trends in forecasted realization time

(4) Leading countries/regions

For each topic, survey participants were asked to specify the current leading country(ies)/region(s) for the technology concerned by choosing one or more answers from the following list: 1) USA, 2) EU, 3) Former Soviet Union and Eastern Europe, 4) Japan, 5) Others and 6) Do not know. The responses were then classified in terms of the percentage shares taken by choices 1) to 6) above and averaged over each field (see Figure 4).

- The "USA" enjoys the highest share in 11 of the 14 fields
- The "USA" share is especially high in the space, life science, information, communication and health, medical care & welfare fields.
- The fields in which "Japan" is placed ahead of other countries/regions are resources & energy, urbanization & construction, and transportation.
- The "EU" is rated relatively high in the environment and transportation fields.
- The "Former Soviet Union and Eastern Europe" scores relatively well in the space field.

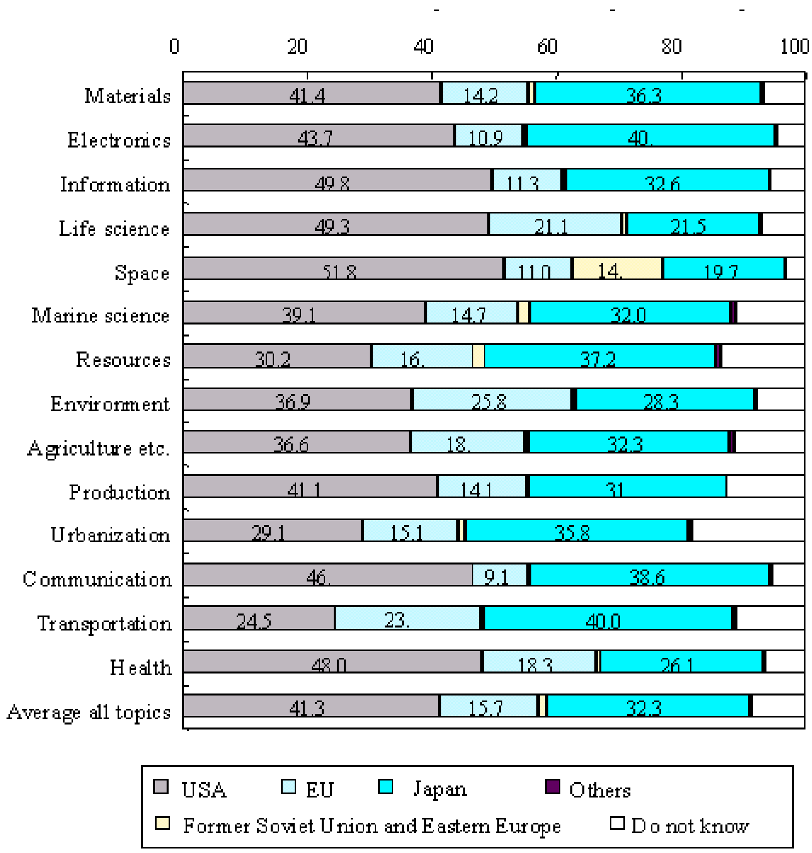

Figure 4 Leading countries etc. by field

Note: In this survey, participants were asked to name "leading countries/regions", with a multiple answer given as a response option. The results, therefore, do not show the perceived relative standing of the listed countries/regions in terms of their technological levels. Rather, they should be taken as something akin to "popularity votes" that these countries/regions attracted. Care should also be taken regarding the effects that the level of exposure that these countries/regions enjoy in Japan can have on the results, with countries/regions about which relatively little information is available in Japan tending to be disadvantaged. Similarly, since the survey topics were prepared in Japan, many of the technologies covered were being pursued in Japan, with a tendency to favor Japan.

(5) Effective measures the government should adopt in Japan

For each topic, survey participants were asked to specify up to three measures that they think the government should adopt to promote the technology concerned by choosing them from the list below, with no selection to be made where participants believed no such measures existed.

1) Foster researchers, engineers and research assistants

2) Enhance systems to promote personnel exchanges among the industrial, academic and government sectors and cooperation among different fields of science and technology

3) Upgrade advanced R&D facilities and equipment and make them available for more widespread use

4) Develop a research base comprising databases, standard reference materials, genetic resources and the like

5) Increase government funding for research

6) Adjust relevant regulations (relax/toughen/establish/abolish)

7) Others

Figure 5 shows the percentage response shares of the above choices as averaged over each field. Regarding all topics average, the shares of the following choices were large: 5) increase government funding for research, 1) foster human resources, and 2) promote personnel exchanges among the industrial, academic and government sectors and cooperation between different fields.

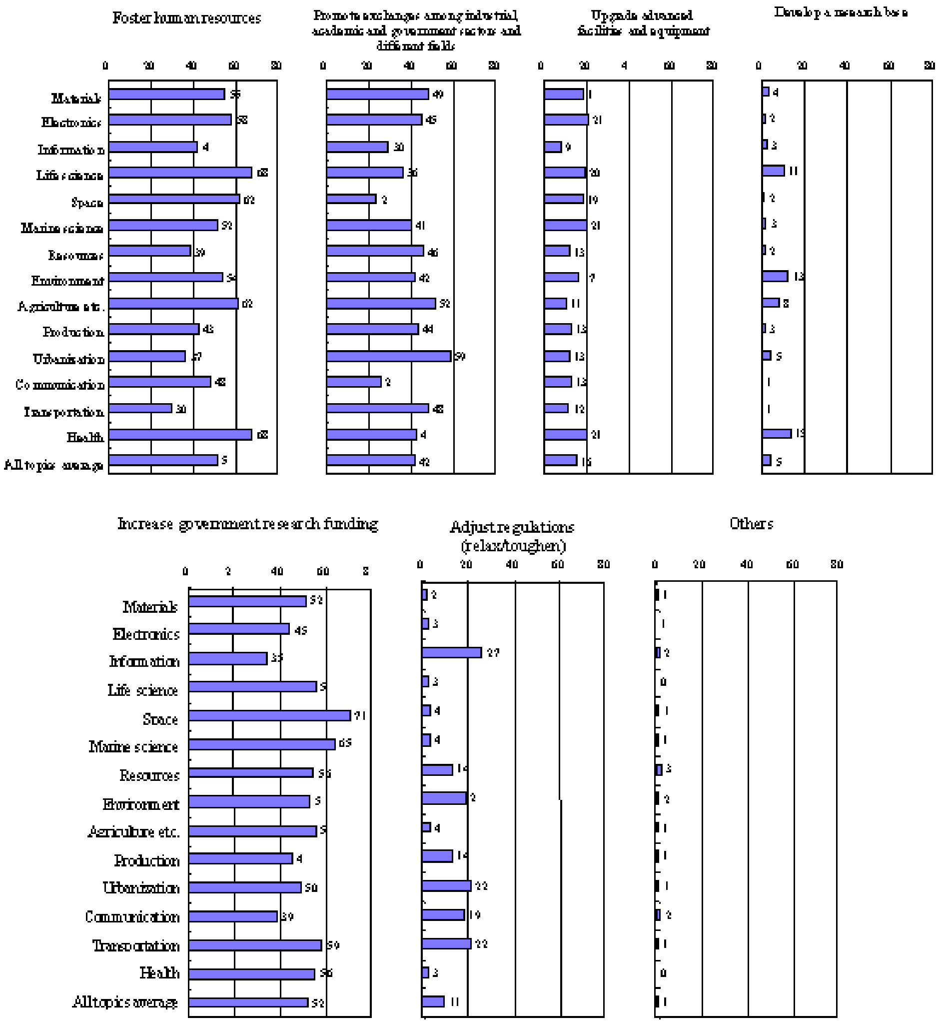

Figure 5 Measures the government should adopt by field

(6) Potential problems in Japan

For each topic, survey participants were asked to specify up to two potential problems that they thought should be considered before pursuing its realization by choosing them from the list below, with no selection to be made where participants believed no such measures existed.

1) Adverse effect on the natural environment

2) Adverse effect on safety

3) Adverse effect on morals, culture or society

4) Other adverse effects

Figure 6 shows the percentage response shares of the above items as averaged over each field.

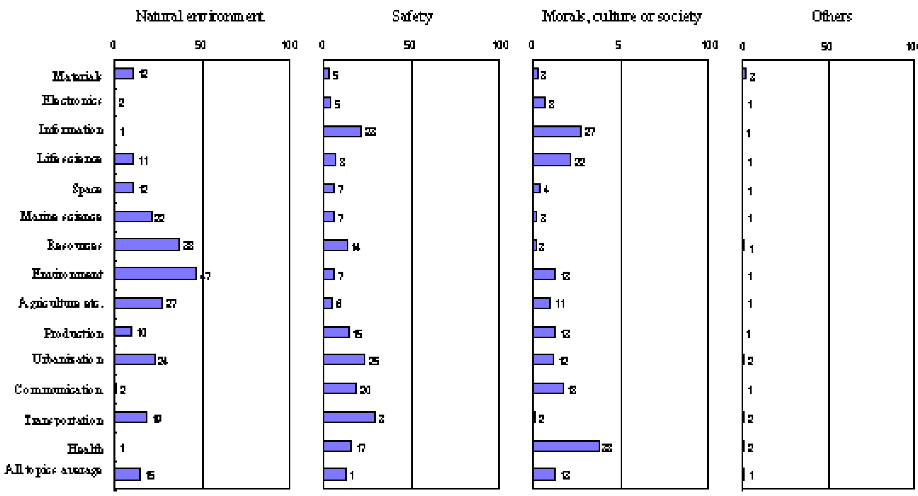

Figure 6 Potential problems in Japan (by field)

≪Examples of topics with perceived great adverse effects≫

"Adverse effect on the natural environment"

- (Environment) Development of storage methods of carbon dioxide at deep sea levels of more than 3,000 m
- (Agriculture etc.) Development of fisheries-resource aquatic organisms with traits advantageous for cultivation, such as high resistance to changes in water temperature, through cell fusion, gene manipulation, etc.

"Adverse effect on safety"

- (Transportation) Practical use of vertical transportation systems for buildings with a transporting capacity per occupant volume which is at least five times that of current elevators
- (Communication) Widespread use of on-line seal-less document preparation services for various official documents such as contract documents

"Adverse effect on morals, culture or society"

- (Health) Practical use of a method to quantitatively assess the level of aging according to chronological age
- (Information) Realization of the deciphering of information recorded inside the human brain by electromagnetic means

(7) Assessment and analysis of the results of the 1st and 2nd surveys

≪Assessment method≫

All topics from the 1st and 2nd surveys were allocated to subcommittees according to their nature, and the subcommittees examined their realization status, centering on subcommittee members, with assessment made in accordance with the following criteria:

- Realized : Realized by 1996
- Partially realized : A part of the topic had been realized by 1996
- Unrealized : Neither of the above

Partially realization is defined as follows:

- Cases where a single topic contains two or more aspects, and while one or more aspects have been realized, there remains at least one aspect that has not been realized.
- Cases where an expression (including adjectives describing performance) in the topic is not quantitatively defined, and its realization is open to interpretation.

Cases where a part of the requirement described in the topic has been realized.

≪Analysis of realization rates≫

1) First technology forecast survey (conducted in 1971)

Table 1 Realization rate of assessed topics in the first technology forecast survey

Division	Field	Assessed topics	Realized	Partially realized	Unrealized	Realization rate (%)	Realization rate including partially realized topics (%)	Unrealized rate (%)
Social development	Improvement of clothing standards	20	6	9	5	30	75	25
	Improvement of housing standards	18	3	5	10	17	44	56
	Leisure	20	5	6	9	25	55	45
	National land and urban development	17	0	11	6	0	65	35
	Improvement of traffic and transportation	20	2	3	15	10	25	75
	Prevention of pollution	20	2	10	8	10	60	40
	Improving education	15	2	6	7	13	53	47
	Subtotal	130	20	50	60	15	54	46
Information	Socioeconomic demands	40	8	20	12	20	70	30
	Information technology	47	19	10	18	40	62	38
	Basic technology	18	9	2	7	50	61	39
	Subtotal	105	36	32	37	34	65	35
Health and medical care	Medical diagnosis and treatment technology	37	9	20	8	24	78	22
	Preventive medicine	9	1	4	4	11	56	44
	Medical care system	12	3	9	0	25	100	0
	Elucidation of life phenomena	9	1	8	0	11	100	0
	Humans and the environment	10	1	7	2	10	80	20
	Medical education	5	0	4	1	0	80	20
	Others	1	1	0	0	100	100	0
	Subtotal	83	16	52	15	19	82	18
Food and agriculture	Development of food material	30	10	11	9	33	70	30
	Systems development	33	8	19	6	24	82	18
	Control methods	20	6	12	2	30	90	10
	Machinery development	13	4	4	5	31	62	38
	Subtotal	96	28	46	22	29	77	23
Industry and resources	Space development	23	8	5	10	35	57	43
	Marine development	25	6	10	9	24	64	36
	Energy development	24	3	3	18	13	25	75
	Resources development	27	3	6	18	11	33	67
	Increasing mining production	38	13	10	15	34	61	39
	Material development	37	18	11	8	49	78	22
	Subtotal	174	51	45	78	29	55	45
Total		588	151	225	212	26	64	36

2) Second technology forecast survey (conducted in 1976)

Table 2 Realization rate of assessed topics in the second technology forecast survey

Field	Assessed topics	Realized	Partially realized	Unrealized	Realization rate (%)	Realization rate including partially realized topics (%)	Unrealized rate (%)
Food resources	69	18	32	19	26	72	28
Forest resources	11	1	7	3	9	73	27
Mineral resources	19	3	8	8	16	58	42
Water resources	8	0	3	5	0	38	63
Energy	21	3	2	16	14	24	76
Environment	47	3	23	21	6	55	45
Safety	18	3	10	5	17	72	28

Family life	29	8	9	12	28	59	41
Leisure	10	1	3	6	10	40	60
Education	24	3	12	9	13	63	38
Health and medical care	41	7	27	7	17	83	17
Labor	10	2	5	3	20	70	30
Transportation	20	1	7	12	5	40	60
Information	53	22	12	19	42	64	36
Construction	20	3	11	6	15	70	30
Industrial production	54	16	21	17	30	69	31
Space development	18	8	9	1	44	94	6
Marine development	28	6	14	8	21	71	29
Life science	22	5	12	5	23	77	23
Software science	27	1	5	21	4	22	78
Total	549	114	232	203	21	63	37

(Reference) Status of Overseas Technology Forecasts

From Europe to Asia and other parts of the world, technology forecasts are regarded as effective tools for the formulation of science and technology policy and technological development plans, and have been put to practice in various countries. For countries which are relatively new to technology forecasts, their benefit is twofold. First, technology forecasts provide comprehensive pictures of their future science and technology development. Second, the surveying process itself contributes to consensus building, while providing participating experts with valuable "learning" experiences.

Germany	1993 Delphi-method technology forecast survey report (questionnaire tables used in Japan's 5th survey adopted) 1994 Outlook for Japanese and German Future Technology ? Comparing Japanese and German Technology Forecast Survey 1995 Japanese and German Technology forecast survey At present, a technology forecast survey that parallels Japan's 6th survey is being undertaken. Approximately 40% of the technological topics set were the same as in the Japanese survey. The survey report is scheduled for release in 1997.
U.K.	A technology forecast survey was conducted in 1994 and 1995. Apart from the Delphi method, the survey featured nationwide panel discussions covering various fields. The next forecast survey is scheduled to take place in 1999.
France	1994 Delphi-based technological forecast survey report (questionnaire tables used in Japan's 5th survey adopted)
Korea	1994 Technological forecast report by the Science and Technology Policy Institute (STEPI)
Thailand	1995 Delphi-based technological forecast survey by the National Science and Technology Development Agency (NSTDA) Aiming to build an APEC Center for Technology Foresight in Bangkok, a feasibility study is being undertaken as an APEC project, with an international symposium held in June 1997. Inauguration is targeted for spring 1998. The center's intended functions include the provision of technological forecast information for member countries and others, education and training of forecast experts, and implementation of joint forecast projects within the APEC region.
Australia	1996 The Australian Science and Technology Council (ASTEC) conducted a comprehensive survey on the needs for science and technology looking towards 21st century.
Indonesia	A small-scale survey based on the Delphi method has been in progress since 1996.
Netherlands	A small-scale survey covering several fields has been under way since the 1980s.
United Nations Industrial Development Organization (UNIDO)	Preparation is under way for the implementation of a technology forecast program in South America. In December 1996, an international conference was held in Bolivia.

Other	Projects are under way or in preparation in various other countries, including Israel, South Africa and Malaysia.