Outlook for Japanese and German Future Technology

- Comparing Japanese and German Technology Forecast Surveys -

National Institute of Science and Technology Policy (NISTEP)

Fraunhofer Institute for Systems and Innovation Research (ISI)

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Foreword by BMFT

The strategic orientation of the German economy towards future markets is a permanent task. In years of world-wide recession, it is even more important to identify the key technologies of the years to come. With the burden of structural unemployment and the environmental challenge, our society seeks new solutions for the next century.

The Federal Ministry for Research and Technology in Germany (BMFT) commissioned several studies and activities to explore the usefulness of technology foresight and to feed orientation knowledge into a strategic dialogue between industry, science institutions and government. However, for long-term foresight, facts and arguments are less consolidated than they are used to be in the daily management of science and technology policy. For the longer-term perspectives of about thirty years the Delphi approach seems to be the most reasonable one. Internationally, the longest tradition with this method is known from Japan.

As one of the foresight activities, modelled after the Japanese experience we transposed this approach to Germany and tried to make the most effective use of the consensus of German experts in their judgement on future trends in science and technology. The German Delphi report was published in summer 1993 and I witnessed a very lively discussion of the approach, the results and the necessity of technology foresight until now.

With this report we are one step further ahead. With the systematic integration of the Japanese and the German results, for the first time, future science and technology perspectives of two large industrial countries may be analysed through large scale surveys. I would like to encourage decision makers in industry, academia and other non-industrial research centres as well as in government to study the similarities but also the distinctions between the assessments of German and Japanese experts, respectively. The best use of the published material in this report is made if the results are discussed and put into practise in this or that way. Certainly, the results of the Delphi surveys are not the truth. There is no absolute truth on the future, but mankind has the opportunity to form and shape it.

With the publication of this comparative report, the activities towards a future orientation of science and technology in Germany are not finished. I shall continue and intensify the strategic dialogue with all interested parties in society on the best way that guides us into a sustainable future.

I sincerely acknowledge the encouragement of both the Japanese and the German Delphi teams and also the preparedness of the science and technology communities in both countries for their participation and openness in the survey.

Dr. Paul Krüger
(Der Bundesminister for Forschung und Technologie)

Foreword by STA

The global environment, population and energy are just some of the broad range of issues that humankind is faced with today. By any means we must resolve these issues and bring about a world in which all people can live without fear and actively pursue their own sense of values.

We in Japan must move forward and build a high quality and sincere living environment which is rich in culture, and also ensure that we protect the magnificence of nature and the environment so that they can be passed on undamaged to future generations. And science and technology is, we believe, a creative activity which can help us to realise our ideals as we move closer to the new century.

In promoting science and technology to keep pace with such demands of the times, we must first clarify the future prospects of science and technology to be promoted, then push ahead with wide-ranging research and development within the industrial, academic, and government sector based on this.

The Science and Technology Agency has been conducting integrated technology forecast surveys every five years since 1971, and Germany also conducted a survey similar to the one whose results were published in 1992.

Comparing the results of these two surveys, we are able to detect conformity or differences in long-term prospects for science and technology in Japan and Germany, two countries with enormous science and technological potential. It goes without saying that to Japan these surveys are an extremely significant tool in helping to develop an understanding of the state of science and technology by way of an international comparison, and to formulate government policy, but the surveys also contain numerous valuable suggestions for the many people engaged in research and development.

In closing, I should like to express my sincere appreciation to the many people who took part in the technology forecast surveys in Japan and German for the important contribution.

April 1994

Satsuki Eda
Minister
Science and Technology Agency

Foreword by NISTEP

The Science and Technology Agency has been conducting technology forecast surveys over many years in an effort to identify the direction of Japan's science and technology development. In November 1992, the Agency published the results of the Fifth Technology Forecast Survey.

The fifth survey is characterised by its large scale and extensiveness: questionnaires containing more than 1,000 survey topics were sent to about 3,000 experts in various fields of research and development in Japan. Such a survey conducted continuously over many years is also attracting attention overseas.

In co-operation with Japan, the German Federal Ministry of Research and Technology conducted a similar survey, and the results of this survey were published in August last year.

A wide-ranging comparative analysis of the results from the two surveys was then carried out with view to clarifying any differences between Japanese and German experts in their views about science and technology in the future and shedding light on issues that may arise as technology continues to advance. This report brings together this analysis, and has been prepared through the joint effort of the National Institute of Science and Technology Policy (NISTEP) and the Fraunhofer Institute for Systems and Innovations Research (ISI), which was responsible for the survey in Germany.

There is general conformity between experts from both countries on important aspects of science and technology and their prospects for realisation, but in individual technological areas and technological topics, differences in the experts' views, reflecting the special characteristics of both countries, are evident. This indicates that science and technology today has become very global, and is closely intertwined with the socio-economic conditions in each country. In this light, it is our hope that this report can be put to widespread use, and will be of benefit in the promotion of science and technology in Japan and Germany.

Interest in this survey is growing in other European countries, and some are planning to conduct technology forecast surveys in the future. Moreover, South Korea recently conducted its own technology forecast survey, so interest in the survey is also growing in the Asian region.

Through this comparative analysis survey, we have come to realise that there is a need to design surveys so that they can facilitate technology forecasts on an international level. To this end, we have started a technology forecast survey with Germany focusing on the technological areas of "materials and processing", "information and electronics", "life sciences", and "environment". On the basis of this survey, we shall begin reflecting the Sixth Technology Forecast Survey from 1995, and we shall be very grateful for your further support and co-operation.

April 1994

Fujio Sakauchi
Director-General
National Institute of Science and Technology Policy

Foreword by ISI

From a European standpoint, the American continent is regarded as the "New World". In science and technology, many intensive relations between the New World and Europe have been established and both continents have benefited therefrom. For many decades, little attention has been paid to developments in Japan. After Japan's economy advanced to become one of the world leaders in many product areas, for many Germans, the country was considered as an exotic new competitor and later on even a rival but less as an interesting country to co-operate with. In the mid eighties, my predecessor, the former Director General of the Fraunhofer Institute for Systems and Innovation Research, decided to devote more of his institute's activities to study science and technology in Japan. After the National Institute of Science and Technology Policy had been established, my institute became one of the first foreign research institutions to sign a formal co-operation agreement with NISTEP. By bilateral exchange of researchers and joint projects, the co-operation between NISTEP and ISI intensified both quantitatively and qualitatively.

It is my pleasure to present this edition of a jointly written report to the public in both countries. I know that the teams in both institutes worked hard on this report, but also towards an adaptation of their different styles in order to publish a report as homogeneous as possible. It is a matter of fact that our two countries are used to different ways of analysing, assessing, describing and reporting.

This report provides a thorough comparison of the Delphi forecast survey performed in Japan and Germany. I think it is typical that the very old Greek tradition of the Delphi oracle to predict important events for the policy, the economy and the survival of mankind in the ancient world has been converted to a modern style of serious foresight in science and technology in Japan. By joining NISTEP in the most recent forecast survey this method comes home to Europe. It is a powerful method to elaborate a basis for priority setting within government, industry and science and for a careful dialogue on strategic options in the science and technology area.

It is the merit of the planning section of the Federal Ministry of Research and Technology (BMFT) to set up several foresight initiatives. The collaboration of NISTEP and ISI in the Delphi project took place as one of the them. The first German Delphi report issued in Summer of 1993 earned widespread recognition, but also criticism. Some observers considered the Delphi approach appropriate for Japan but not for Europe, because of the different cultures, including the high degrees of scientific freedom in Germany. With this report a systematic comparison between the assessments and evaluations of many Japanese and German experts is provided.

I am grateful to the funding agencies in Japan (STA) and Germany (BMFT) which enabled the researchers in my institute and those at NISTEP to co-operate and to perform this interesting, comparative study. I also acknowledge the highly motivated and engaged teams as well as the labour invested in the surveys in both countries by the many respondents to the questionnaires. This excellent co-operation is clearly an encouragement to continue.

April 1994

Frieder Meyer-Krahmer
Director General, Fraunhofer Institute
for Systems and Innovation Research

1 General Method

1.1 Review of Western Literature on the Delphi Approach

Research and technology policy decisions and entrepreneurial innovation management require a planned, systematic, organised approach

- which analyses the state of a technology (*technology monitoring*),
- explores its development possibilities (*technology foresight*),
- estimates the direct and indirect impacts of its application on the economy, the environment, the health system, society and other areas (*technology impact assessment*),
- assesses these impacts based on defined aims and values, compares other desirable developments and formulates activity and organisation possibilities from these (*innovation strategies or technology policy studies*).

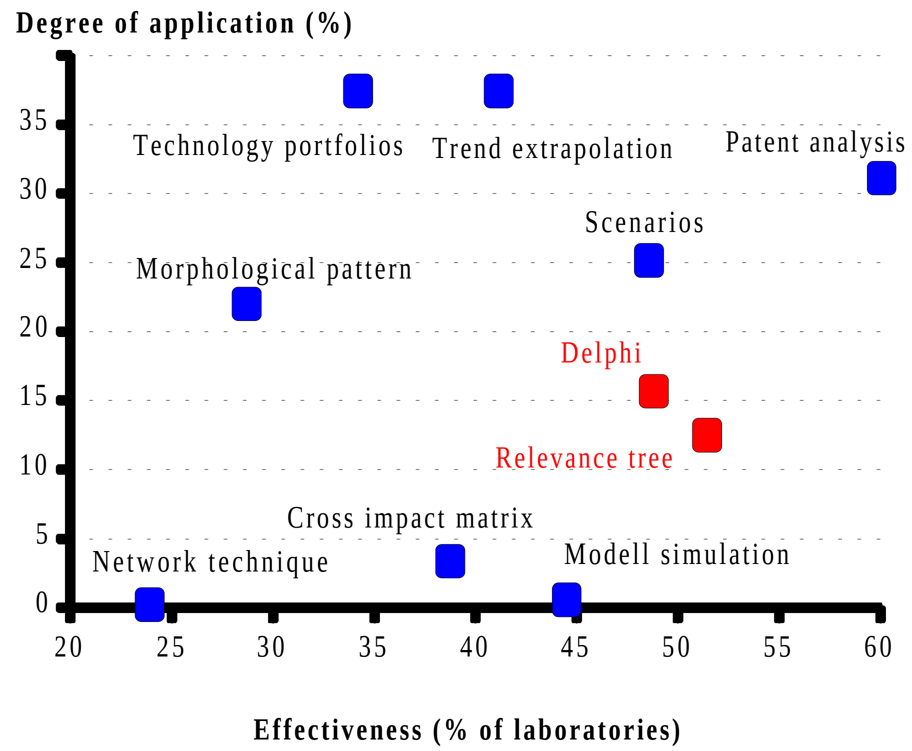
The Delphi process is, in a broader sense, a specialised methodology for technology assessment. Generally speaking, it is based on heuristic methods of scientific problem solving, which are described and applied particularly in systems analysis and systems technology. The classical repertoire of technology assessment can be split into qualitative and quantitative methods, although a mixture of the two is frequently used in practice. The Delphi survey has both characteristics and can be used to define and structure an area under investigation as well as to forecast and assess technology trends.

The Delphi survey is a way of finding ideas, forming opinions and making forecasts which systematically determines the insights and assessments of selected specialists. The survey results are presented to the experts involved once or several times to allow them to examine their views in the light of the other experts' opinions and, if necessary, correct any deviations. The success of the method depends heavily on the selection of the specialists to be questioned. It must be borne in mind that specialists who are involved in a particular development often tend to rather optimistic estimates. An important *rule* results from this for such surveys: well-informed specialists who are not actively involved in a particular area should be encouraged to express an opinion about that area. This rule has to be referred to in connection with the discussion on concrete results. Because the Delphi method is convergence-forming, it favours majority opinions and causes deviating views to conform.

Scenario formation, the Delphi approach and the relevance tree method are among the most effective methods for technology foresight. They are demanding, complex and expensive to perform and therefore less widespread. The *scenario method* has to refer to a particular scenario (energy forecasts, CO_2 forecasts etc.) and is hardly suitable for a detailed and at the same time comprehensive description of technological development. Use will be made of the scenario technique as a starting point in Chapter 4.1. The *relevance analysis* is basically a problem-specific interpretation of an interconnected structure which is used to make a complex, multiphase structure of conditions or bundle of impacts of a desired or expected event transparent. Even if it does not define the method used to gain the knowledge from which the relevance "tree" is constructed, it is a proven method, used not only to clarify the structure and representation of known correlations but also to discover unsuspected dependencies. The relevance tree was applied at roughly the same time as the Delphi approach in Germany, while setting up the study "Technology at the Threshold of the 21st Century" (see Grupp, 1993) by linking an extensive list of individual topics of technological development to a long list of relevant criteria. A quantification of relevance trees is only useful for well-structured problems for which empirical data are available. In the case of evaluating technological themes using economic, ecological and social aspects, a quantification is not rational and was therefore omitted in this project. In future foresight activities, a partial integration of the relevance tree approach with the Delphi approach seems to be desirable.

Figure 1.1-1 shows that the Delphi approach together with scenario techniques and the relevance tree method is among the most reliable methods of long-term observation but not very common due to the large amount of time and energy involved. For long-term investigations, in particular, (20 - 30 years) there are hardly any alternatives to specialists' estimates, so that the strengths of the Delphi approach are especially apparent here. Patent statistics is very effective, but the forecast power is limited to about five years, i. e. medium-term. The data in Figure 1.1-1 originate from a Japanese survey of 247 research institutes in 1989 (NISTEP/IFTECH, 1991); a similar comparative investigation of the degree of application and the effectiveness of the various foresight tools from the Western world is not known.

Figure 1.1-1: Degree of application and effectiveness of technology foresight tools in Japan (NISTEP survey 1989)



The Delphi method was developed by the RAND Corporation in the US in the 1950's with the aim of making better use of the interaction in research groups (Rowe et al., 1991). (The RAND Corporation is a large research company which handles many questions of public interest from legal and educational problems to defence policy and nuclear safety). Questionnaires are sent repeatedly to a group of specialists, the repetitions are known as "rounds". The questionnaire of the second and all consecutive rounds does not only repeat the questions of the first round but also transmits information about the extent of group consensus already achieved among the people questioned. The questionnaire is, therefore, the medium for group interaction (Martino, 1983). It is generally the case that a convergence of opinions takes place from the second round onwards. Usually very diverse valuations on each individual question are presented to those questioned, but they are not always prepared to be influenced by their colleagues' views to the extent of changing their original opinions (Bardecki, 1984). The participants in a Delphi survey are entitled to stick to their original judgement just like the participants in a working group who confront each other personally in conferences. One advantage of the Delphi method that is cited is that it is easier for those involved to change their opinion without loss of face as the change of opinion happens "on paper" (Martino, 1983).

In the following, several critical appreciations of the Delphi approach are presented which are nearly all based on investigations in the USA. The considerable experience gathered with this type of investigation in Japan is very seldom part of such criticisms.

Woudenberg (1991, p. 132) hints at the origin of the term which recalls the *Greek oracle*. The term was coined by the RAND employee Kaplan, a qualified philosopher, who was familiar with the ancient legend. It was his task to improve the quality of experts' predictions for strategic decisions, especially in the area of research and development. However, the first experiment with the Delphi method was conducted in 1948 in order to predict the winners of horse races and so optimise the betting (there are no records of how correct the predictions were). The investigations following this were kept secret due to their military nature and the first publications about them only appeared in 1963 (op cit).

The oracle of Apollon at Delphi, for which the approach is named, was operated by a team of priests. The priests gave answers to everyday problems and to state political questions via a medium, known as the Pythia, who was a priestess able to make prophecies due to being under the influence of "divine madness". The place name "Delphi" comes from the dolphin into which Apollon changed himself according to Greek mythology in order to hire the first oracle priests, who were mariners. Archeological discoveries and historical investigations (e. g. Parker, 1956) have made it clear that the oracle was not only intended to predict the future

but also to guide and direct the world's history at that time - an interesting point for the technological variants of the modern era.

When comparing the modern Delphi "predictions" since the RAND concept, it must be borne in mind that there are significant differences between current practice and the original concept (Rowe et al., 1991) so that systematic comparisons between different Delphi projects are unrealistic. It came, therefore, as no surprise that a dispute about the value of Delphi investigations began in the literature of the 1970's - the years following the first publication of a Delphi project in 1963 - which can be linked to very optimistic and extremely pessimistic exponents (see Rowe et al., 1991). Delphi investigations do have certain advantages. However, any attempt to present the method as virtually faultless must fail. It has been found that every method which allows group interaction is superior to those based on the assessments of knowledgeable individuals. It cannot be maintained that the Delphi approach is more exact than other opinion forming processes in groups. Neither is it true that the consensus on certain evaluations is solely dependent on the distribution of relevant information to those questioned, group pressure plays a decisive role with regard to conformity (Woudenberg, 1991).

If the *psychological processes* that accompany a Delphi questionnaire are examined, it must be assumed that the persons involved cannot be sure of the appropriate answers. They look for external "anchors" to which they can attach their judgement. The transmission of average values from the judgement of other experts has such an "anchor function" in Delphi projects where the significance of this information depends ultimately on the credibility that the individual attaches to the anchor information (Bardecki, 1984, p. 283). Personal characteristics play an additional role, the extent to which the specialist wants to remain in *cognitive dissonance* to the group's opinion. A cognitive dissonance exists when knowledge, opinion or attitude are in disagreement with each other. If a person is not able to bear discord, the desire to assimilate is strong. In such cases, if the discord is great the corresponding pressure on the participant to assimilate also increases. In general, the agreement of an individual with the group's opinion reduces the feeling of discord which that person has to bear.

There are parallels between the psychological problems of attitude changes and the behaviour when answering Delphi questionnaires (Bardecki, 1984, p. 291). If a university lecturer or an industrial researcher has already presented his specific evaluations in writing, or orally (in lectures or in front of the company's board of management) then the quashing of this evaluation via a Delphi majority can affect his self-confidence, career expectation or self-knowledge. Is it surprising that the historian Parker wrote about the classical Delphi model "If due allowance is made for the circumstances, modern psychology will find no special difficulty in accounting for the operations of the Pythia" (1956, p. 38)?

These investigations and considerations show that general personality characteristics must be taken into account in addition to the specialist expertise in the formation of a Delphi result. It can be attempted to control such influences by making the participants reveal something of their personality but this was not considered useful in either the Japanese or the German investigation.

What role does the specialist knowledge of the participants play alongside personality? Generally it should be able to be assumed that those with greater knowledge of a subject will be able to make a more accurate judgement of future development. The following findings are in contrast to this assumption: technical and scientific activities are embedded and interact with a complex social structure. The necessary decisions, for example whether to expand into a new working area are only rational to a limited extent because they depend on significant insecurities and job expectations (Blume, 1992). Several sociologists who are involved in investigating scientific and technical processes among them Burns (1985), Law and Callon (1987) and Krupp (1992), emphasise the abilities of individuals who are involved in research and innovative processes to mobilise social, economic and political resources in order to continue their work. It is therefore not implausible to assume that active specialists are more positively oriented towards their particular subject than towards other important areas in science and technology. They select research tasks in areas that promise to yield good results or are career conducive. The tendency to overvalue their own work is interpreted as *bias* in the literature. Shrum (1985) found, in more than 100 interviews with experts, not only that this bias exists but that it is more apparent in less innovative sub-areas and leads to a stronger inertia in specialist areas where the immanent future prospects are less favourable.

Rowe et al. (1991) report on a special Delphi experiment in which a particularly knowledgeable expert was introduced into an existing group of specialists and whose exchanges with the others actually resulted in the validity of the statistical valuations of this group being reduced.

General criticisms of the instrument of opinion research will not be discussed here. It can be assumed that the so-called valuations may be understood as strategic signals to an unknown extent. Participants who want to shift the group's opinion will assume extreme positions, especially if the purpose of the study is misunderstood or its impact on technology policy is given too much weight (see the corresponding notes on ancient Delphi).

How many *rounds* are effective in a Delphi study? According to the literature, it has been shown that in nearly all the Delphi investigations, more or less all the improvements to the statistical judgements took place between the first and second rounds. In only a few studies was the accuracy of the valuation improved further after the second round (Woudenberg, 1991). In the few cases in which a third or even fourth round was carried out, it was often the case that "notorious" outsiders no longer participated and others changed their opinion against their conviction in order to put an end to the continued questioning (Bardecki, 1984). As further rounds involve considerable expense, it can be concluded from the literature that two rounds are optimal.

There remain two serious problems with the Delphi approach. The questions asked in the first round do not result from the Delphi approach itself but have to be created and selected in another context. They are "external" to the survey. It is definitely not a trivial task to formulate these questions if a good result is to be obtained and, indeed, in current investigations, creating the initial questionnaire often consumes the greatest amount of time. The questions of the German Delphi project are based on the question catalogue developed in Japan which was used in the fifth Japanese investigation. In order to achieve the most comprehensive comparison of the data, a correct translation of the complex questions into German was necessary which turned out to be extremely difficult (see Chapter 1.4).

The teams involved in the joint project, NISTEP and ISI, attempted to adopt the Japanese catalogue of questions with all its advantages but also its restrictions. If any of the questions had been altered in the German survey, it would not have been clear whether any differences of opinion between Germany and Japan were real or the results of such *alterations to the questions*. For this reason, the German team decided it would be better to follow the Japanese version exactly and now, after presentation of the results, to enter into a more accurate analysis of its strengths and deficits resulting from translation, cultural background or else.

The second difficulty that has to be expected from a parallel study in two countries results from the fact that the specialists are involved in nationally different circles. Although it is in the nature of science and technology that they take place on an international level, collective prejudices can occur due to *national or cultural habits* and peculiarities. The language barriers, and the different way of thinking between Japan and Europe may cause additional collective information deficits. Not all deviations in the judgements can necessarily be regarded as weakening the validity of the project, they may well be a result of different cultural contexts and should therefore be examined in this report.

Finally, it should be pointed out that the most experience with comprehensive Delphi investigations has been made in Japan, a country that is rarely considered in the English literature on technology evaluation. The Delphi approach fits in very well with the Japanese mentality. There are very few references to the Japanese Delphi methodology in European publications, for the few exceptions see Martin and Irvine (1989) and Martin (1992). The belief that Japan is the leading nation in the application of diverse Delphi investigations is based on the following observations. It is true that the number of such investigations in Japan is small but they were very extensive and complex with regard to the number and detail of the questions and a large number of specialists took part in them. The number of smaller Delphi surveys from the United States is greater but they are more limited as only broad questions were asked and only a few experts were involved. For example, the Graduate School of Business at the University of Southern California regularly conducts Delphi investigations which cost about US $ 50,000 and involve the consultation of several dozen up to 100 experts. In contrast, the Japanese Science and Technology Agency (STA) conducts a very comprehensive Delphi investigation every five years which has become a fixed element of Japan's technology policy. Since 1971, there have been five such surveys and it was the last one, the fifth, that was the model behind the German survey (NISTEP/IFTECH, 1992). In Japan, more than a thousand detailed questions and several thousand experts are usually involved.

The five Delphi surveys carried out in Japan since 1971 have had astonishingly little impact in Europe and are hardly mentioned in the specialist literature on technology forecasting. As the second and third Delphi forecasts are only available in the Japanese unabridged versions, this can be explained by the language barrier. But the first Delphi investigation was completely translated into English (Martin and Irvine, 1989) and the fourth one published as a detailed book in English with 258 pages (IFTECH, 1988) so that a critical discussion of these could well have taken place in the literature. Notable exceptions to the general ignorance of the Japanese surveys are Martin and Irvine from the Science Policy Research Unit (SPRU) of Sussex University, who reported on several occasions on the Japanese unabridged forecasts (Irvine and Martin, 1984, Martin and Irvine, 1989, Irvine, 1988, Martin 1992). The fifth Japanese Delphi study appeared in the summer of 1993 in English at about the same time as the German report in German.

In contrast to other prospective analyses, the 30 year prediction of science and technology in Japan is aimed neither at a particular target group nor is it embedded within a concrete policy. The general aim of the initiating authority, the STA, is rather to produce a comprehensive overview of significant innovative trends in science and technology in order to contribute to the state planning process in the field of science and technology policy and to be able to support industrial associations with relevant information (see Chapter 1.2).

The five surveys carried out were organised by various contractors and had differently assembled consultation groups. However, a remarkable continuity was still achieved as the steering committee in each survey was headed by the same person, previously the director of Mitsubishi's research institute and a man well-respected in Japanese research circles.

According to Martin and Irvine's interpretation (1989), the Japanese target groups in politics and the economy are not bothered about an exact prediction of future events. They are much more concerned with information about gradually occurring trends in science and technology of which management in research and development circles should be aware. Seen in this light and following Martin and Irvine's Western assessment, the most important strengths of the Delphi approach are listed below:

- The scientific and technological community is forced at periodic intervals to think seriously and in detail about significant trends and their relation to important socio-economic priorities and obstacles. This gives them a broader outlook beyond the day-to-day business in the laboratory.
- Due to the participation of experts from scientifically oriented enterprises and other research establishments, ministerial departments are put in the position of being able to perceive trends with reference to future demands on national innovation. Projected industrial and social problem areas can be systematically presented.
- A survey of this kind covers all the important areas in science and technology and is capable of contributing to an overall approach by a suitably disciplined handling of individual topics. In particular new created and interdisciplinary technology areas can very early be introduced into traditional fields. In this way, areas such as information technology or "*mechatronics*" were identified in the first Delphi surveys in Japan at a time when the general discussion had not yet been able to classify these cross-discipline subjects. The same thing happened in the 80's e.g., with questions on the fusion of information technology and material sciences or with asking for "*biotronics*".
- The consensus-forming aspects of Delphi surveys are particularly important for Japanese society as leading scientific, governmental and private researchers can exchange their opinions about national forecasts of medium and long-term research and development aims in a written dispute without loss of face. This procedure contributes to a clearer reflection of social conditions of the technological possibilities just as much by its method as by its results.

These explanations were completely corroborated by two members of the German Delphi team during an interview at the STA in 1993. After presentation of the fifth Japanese survey it was still found to be true that the *process of collecting the information is at least as important as the presentation and discussion of the results*.

1.2 Overview of the Previous Delphi Experience in Japan

The Science and Technology Agency has conducted a technology forecast survey every five years since the first survey using the Delphi method in 1971. In the five surveys carried out to date, the number of topics has increased with each survey. The forecasted time of 30 years has been the same for all surveys (Table 1.2-1). The surveys are large-scale and very extensive, covering all technological areas, and such surveys carried out on a regular basis for an extended period are indeed without parallel in the world.

From the fifth survey the National Institute of Science and Technology Policy (NISTEP) assumed the responsibility of conducting the survey and compiling the results. NISTEP conducted the fifth survey over three years from 1990, and published the results in November 1992 (IFTECH/ NISTEP, 1992). The fifth technology forecast survey covered 1,149 topics classified into 16 technological areas. In the first round, responses were received from 2,781 experts in various technological fields, and the second questionnaire was answered by 2,385 experts. The forecasted period was thirty years starting from 1991 (the survey year) to 2020.

Table 1.2-1: Changes in the coverage of Japan's Technology Forecast Surveys

	Survey period	No. of technical areas	No. of topics	Forecasted period	No. of effective responses
First survey	**1970-1971**	**5**	**644**	**30 years to 2000**	**2482**
Second survey	**1976**	**7**	**656**	**30 years to 2005**	**1316**
Third survey	**1981-1982**	**13**	**800**	**30 years to 2010**	**1727**
Fourth survey	**1986**	**17**	**1071**	**30 years to 2015**	**2007**
Fifth survey	**1991**	**16**	**1149**	**30 years to 2020**	**2385**

An absolutely vital part of the technology forecast survey using the Delphi method is preparing effective technological topics. For the Fifth Technology Forecast Survey, NISTEP formed a forecast committee comprising 30 experts from various fields to set the technological areas. After the 16 areas had been set, 13 subcommittees, each comprising 5-10 experts, were established under the technology forecast committee to decide upon the framework to prepare suitable topics that could explore the essence of technological progress in each of the areas. The individual topics were then prepared within this framework.

Covering all 16 areas, questionnaires were structured in exactly the same way, and included such variables as the degree of expertise of the respondents, the degree of importance, the forecasted realization time, the degree of certainty, the necessity of international joint development, constraints on the realization and, in the second round, a comparison of the current R&D level between Japan and other countries. The committees, then, selected experts in each of the 16 technological areas to answer the questionnaire. Subcommittees gave special consideration in the selection process to ensure that there was no imbalance among industry, academia and government, and respondents were also asked to assess their own degree of expertise.

To ascertain the extent to which the results of the technology forecast surveys are used, in 1990, NISTEP conducted a user questionnaire survey of people and organisations that bought the Fourth Technology Forecast Survey Report which was published as a book. 247 responses were received (Table 1.2-2). About 70 per cent of the respondents indicated that they had bought the report for using it in R&D and technology development or for the formulation of business plans, and of these, about 73 per cent indicated that the information contained in the report had been very useful or useful to a certain degree in achieving these aims.

Table 1.2-2: Survey on the use of technology forecasts

1. What is your interest in Science and Technology Agency technology forecast surveys?

(1) Technologies

a) To gain a wide-ranging understanding about future trends of technology in various areas. 49.4%

b)	To grasp future trends of specific technological areas or technologies of interest.	48.6%
c)	Others.	1.2%
d)	No response.	0.8%
(2)	Forecasted time	
a)	To grasp long-term technological trends (at least ten years ahead).	24.7%
b)	To grasp medium-term technological trends (5-10 years ahead).	60.7%
c)	To grasp short-term technological trends (up to five years ahead).	11.7%
d)	Others.	0.8%
2.	What Science and Technology Agency technology forecast information have you used? (multiple answer)	
a)	Subject matter of the forecast topics itself.	59.9%
b)	Importance assessment.	51.0%
c)	Realization time.	76.1%
d)	Limitations on realization (technological, economic, social limitations).	37%
e)	Methods of promoting R&D (independent R&D, introduction of technology, international joint development).	16.2%
f)	Main R&D promoter (government, private sector, both government and private sector).	12.6%
g)	Government measures (funding, human resources, systems, etc.).	13.8%
h)	Comments (minority opinions).	18.2%
i)	Others.	0.4%
3.	How useful has the information been?	
a)	Very useful.	11.7%
b)	Useful to certain degree.	61.1%
c)	Cannot say either way.	19.0%
d)	Not very useful.	4.9%
e)	Not useful.	2.0%
f)	Others.	0.4%
g)	No response.	0.8%

4.	How significant is the information?	
a)	Information is extremely important and necessary.	58.7%
b)	Information is worthwhile to have.	36.4%
c)	Information is not very important (not particularly necessary).	2.0%
d)	Do not know.	0.4%
e)	Others.	0.8%
f)	No response.	1.6%
5.	How do you gather information about technological trends when formulating R&D or technology development plans or business plans? (multiple answer)	
a)	Carry out independent technology forecasts (without using external agencies).	14.6%
b)	Use external agencies (think-tanks; commission surveys).	35.6%
c)	Use information from Science and Technology Agency technology forecast.	55.1%
d)	Use publicly available technology-forecast-related information by external agencies other than the Science and Technology Agency.	47.8%
e)	Use internal technology-forecast-related information.	30.4%
f)	Others.	9.3%
g)	No response.	3.2%

It is always difficult to evaluate the impacts of a survey like the technology forecast surveys but with the questionnaire shown above, concrete influences on Japan's research and development as well as technology developments in general can be underpinned. Beneath this internal survey, independent foreign researchers (Martin and Irvine, 1989) identified the major strengths of the Delphi method in their survey (see previous chapter 1.1).

In contrast to other technology forecasts, this forecast survey applying the Delphi method is not addressed to specific persons in academia or industry and is not embedded into a special policy process. The main objective of the Science and Technology Agency is, moreover, to receive an overview of important innovation trends in science and technology in order to add information to the planning processes of the state in science and technology policy and to provide industry with this information.

1.3 Basic Statistics

There are 1,146 comparable technology forecast topics in the Japanese and German surveys. German technological topics are basically a direct translation of the 1,149 Japanese topics into German of the technology forecast topics drawn up in Japan. Three that are not suitable for the German research have been excluded. Moreover, while there have been minor amendments such as the replacement of "Tôkyô Bay" with "Rhine River", overall there is little difference. For details see chapter 1.4.

Table 1.3-1: Response to the questionnaire

Field	Number of topics	Responses			
		Japan		Germany	
		1. Round	2. Round	1. Round	2. Round
Materials and Processing	108	252	203	77	64
Information and Electronics	106	187	151	66	47
Life Science	98	217	181	76	66
Space	46	294	248	33	29
Particles	40			25	22
Marine Science and Earth Science	82	288	255	46	32
Mineral and Water Resources	39	103	89	43	37
Energy	51	156	144	178	146
Environment	50	150	119	76	62
Agriculture,Forestry,and Fisheries	73	232	201	56	52
Production	72	128	116	66	55
Urbanization and Construction	65	137	123	46	36
Communications	65	133	115	89	66
Transportation	62	202	182	65	53
Medical Care and Health	108	164	139	52	38
Culture and Lifestyles	81	138	119	62	53
Total	1146	2781	2385	1056	857

The 1,146 comparable topics are classified into 16 technological areas (Table 1.3-1), and in principle, each of the topics is represented by one of the following keywords to indicate the stage of the technology, from basics to application.

Elucidation:	To scientifically and theoretically identify principles or phenomena.
Development:	To attain a specific goal in the technological aspect. For instance, this refers to the completion of a first prototype.
Practical Use:	To be practically used after being proved economically acceptable. For instance, this refers to the completion of the first object that can actually be presented for practical use.
Widespread Use:	To be widely and commonly used after an object is put to practical use.

All topics were classified on the basis of these keywords as listed in Table 1.3-2 by the maturity of technology, so that a comparative analysis could be made between technological areas, corresponding to the "vertical divisions", and a comparative analysis for each technological stage, corresponding to "lateral divisions". However, topics that do not clearly contain a keyword have been classified according to the judgement of the National Institute of Science and Technology Policy. Of all 1,146 topics, there are 87 topics under "Elucidation", 344 under "Development", 476 under "Practical Use", and 239 under "Widespread Use".

The technology forecast surveys by Japan and Germany were performed using the Delphi method in which respondents' opinions were constricted through two questionnaires. The Delphi method is one in which the same questionnaire is given repeatedly to a large number of people to constrict the opinions of the respondents. From the second questionnaire respondents receive feedback on the results of the previous questionnaire(s), and, observing the overall trend of opinions, respondents are able to reassess the questions in the questionnaire. This aspect is the key difference between this method and ordinary questionnaire methods. Respondents who are not confident in their answers will generally tend to support the majority opinion, so it is possible to change opinions (see also section 1.1).

Table 1.3-2: The number of topics per stage and area

	Elucidation	Development	Practical Use	Widespread Use	Total
Materials and Processing	2	50	49	7	108
Information and Electronics	3	37	40	26	106
Life Science	37	45	12	4	98
Space	0	26	20	0	46
Particles	5	14	17	4	40
Marine Science and Earth Science	9	19	43	11	82
Mineral and Water Resources	1	5	22	11	39
Energy	0	6	29	16	51
Environment	16	11	16	7	50
Agriculture, Forestry and Fisheries	2	25	34	12	73
Production	0	12	29	31	72
Urbanization and Construction	0	10	29	26	65
Communication	0	14	38	13	65
Transportation	0	14	37	11	62
Medical Care and Health	9	36	44	19	108
Culture and Lifestyles	3	20	17	41	81
Total	87	344	476	239	1146

In selecting people for the Japanese survey, NISTEP looked at experts in each of the relevant fields in industry, academia and government from the list of respondents to the Fourth Technology Forecast Survey, and after adding new respondents to compensate for any bias or shortages in the different fields, the various subcommittees confirmed the fields of expertise of the respondents, and finally made their decision as to who would receive the questionnaires. For the first part of the survey, NISTEP sent questionnaires to 3,334 people, and for the second part, questionnaires to the 2,781 people who responded to the initial questionnaire were sent. NISTEP received 2,385 responses to the second questionnaire, a response rate of 86 per cent.

In Germany, the selection of people for the survey was done from a general data base on experts from all regions, including the regions of the former East Germany. A total of 6,627 questionnaires were sent to 3,534 people. For the German survey, because no previous mailing list was available, there was more uncertainty on the fields of expertise of the people to whom the questionnaire would be sent, so in many cases, people were sent more than one questionnaire. In the second part of the survey, ISI sent questionnaires to the 1,056 people who responded to the initial questionnaire, and of these responses to the second questionnaire were received from 857 people, a response rate of 81 per cent.

In the Japanese survey, the areas of Space and Particles were handled as a single area, but were separated for the final calculation. In Germany, in the area of Energy, besides the database selection, members of the Society on Energy Technology of the Association of German Engineers and members of the Forum for Future Energy were asked to answer the questionnaires. Thus, intentionally, there were about as many respondents in the Energy area as in Japan.

The response rate to the second questionnaire was quite similar: 86 per cent in Japan and 81 per cent in Germany. A classification of respondents by gender, age, occupation, and occupational category shows that while the percentage of younger respondents tended to be slightly higher in Germany than in Japan which might be due to the fact that in many cases, the head of the department handed the questionnaire over to younger employees who - in Germany - inserted their own name, but for formal reasons, tended to write the approached person's name in Japan. Percentages were generally the same in the other classifications (Table 1.3-3).

However, in Germany for the second questionnaire respondents were not asked to fill in the item on gender, age, occupation, and occupational category, a second time, so that the results of the first questionnaire have been used.

Table 1.3-3: Details of respondents

Nation	Sex		Age group					
	Male	Female	20's	30's	40's	50's	60's	70's or older
Japan	99%	1%	0%	5%	31%	45%	18%	1%
Germany	96%	4%	2%	20%	25%	41%	12%	1%

	Occupation				Occupational category	
Nation	Working for private companies	Working for universities	Working for public research institutes	Working for organisations	Engaged in R&D	Others
Japan	38%	37%	15%	10%	79%	21%
Germany	41%	38%	15%	6%	81%	19%

For details on the Japanese and German technology forecast survey refer to:

Japan:
The Fifth Technology Forecast Survey
- Future Technology in Japan -
NISTEP REPORT No. 25, November 1992, NISTEP

Germany:
Deutscher Delphi-Bericht zur Entwicklung von Wissenschaft und Technik
August 1993, BMFT

1.4 Special Aspects of Transposing the Japanese Delphi Approach to Another Country

To achieve the acceptance of transposing a Delphi survey from Japan to Germany is a difficult task. As the most experience on Delphi forecasts is available in Japan, it was decided to draw on the same pattern of survey in Germany. At a first step, the questions had to be translated in order to achieve the best possible comparability. Then, the questionnaires had to be prepared, send out, re-collected and a first data analysis for the second round had to be made. The second round had to be finished before the Japanese institute published an English version of its data analysis in order to guarantee a "double blind investigation" meaning that the German experts do not know the Japanese results. Therefore, the German Delphi was carried out under tremendous time pressure.

The greatest problems were posed by designing and creating the German questionnaire. The translation of the questions and the questionnaire from Japanese into German proved to be very difficult and time consuming. After a first translation by specialist translators it was found that not only the formulation but also the content of individual questions and specialist terminology caused major problems. Further reworking of the individual subject areas by internal and external experts was necessary. These experts, however, did not speak Japanese and so were unable to judge whether the sense of the original questions was retained after the revision. In order to check this, the questions were translated back into Japanese by a Japanologist, modified in form or content and linguistically adapted to meet the experts' high standards.

The final questionnaire was, therefore, a compromise between technical terminology and retention of the originally Japanese character of the questions. It cannot be denied that some subjects "sound Japanese" or incorporate the Japanese way of thinking and are therefore difficult to understand for Europeans. The aim of ensuring comparability made it impossible to avoid such a compromise between good language and the correct specialist terms.

Some problems of adaptation were caused by changes concerning the content and order of the technological areas. In the Japanese questionnaires of the first round, the fields Space and Particles were still united as technology area number 4 and the questionnaires of only fifteen different technological areas were sent out. But for the analysis in the Japanese report, area number 4 was split into Space and Particles. Independently, the German Delphi team decided to separate these fields from the beginning (the questions and areas were translated from the questionnaire of the second round, where only 15 fields existed) into Space and Particles because it made more sense to approach different science communities. Therefore, the response rate for each of the two areas was not very high (chapter 1.3) but highly reputed experts could be approached (chapter 2.1).

For the German questionnaire, it was decided to change the order of the technological areas, too. Thus, Particles remained field number 4, but Space was located between Communications and Transportation to keep a certain context both to communication satellites and transportation of man and goods to orbit or planets. In the Japanese report, the common questionnaire was discussed separately in the report as Space (no. 4) and Particles (no. 5). Therefore, the order of the Japanese and German technological areas changed in both cases but not in the same way. Hence, in the comparison analysis and charts of this joint report, abbreviations (codes) for the specific technological fields were introduced. The key is shown in table 1.4-1.

As a consequence of the different order, in the text, referring to one question, two numbers of technological areas are given e.g., topic J 11-58/ G 10-58 means question number 58 in the Japanese technological area 11 and the German field no. 10 which is both "Urbanization and Construction" abbreviated as "urb". If the area does not differ, it is only written once e.g., J/G 3-42, meaning question number 42 from the technological area of Life Sciences in both countries. One has to be careful with area number 2 (Information and Electronics), where in the Japanese survey, topic number 60 was finally left out so that the order within the area changed e.g., topic J 2-70 is equivalent to G 2-71. Here also, both numbers are given. The three topics left out in the German questionnaire caused no problem in codes, because the original numbers were kept. In the comparison, the four missing topics in either country were not taken into account.

Table 1.4-1: Enumeration and abbreviations for the technological areas in Japan and Germany

J.-No.	G.-No.	Technological Area	Abbreviation
1	1	**Mat**erials and Processing	mat
2	2	**Inf**ormation and Electronics	inf
3	3	**Lif**e Sciences	lif
4	13	**Spa**ce	spa
5	4	**Par**ticles	par
6	5	**Mar**ine Science and Earth Science	mar
7	6	**Min**eral and Water Resources	min
8	7	**Ene**rgy	ene
9	8	**Env**ironment	env
10	9	**Agr**iculture, Forestry and Fisheries	agr
11	10	**Pro**duction	pro
12	11	**Urb**anization and Construction	urb
13	12	**Com**munications	com
14	14	**Tra**nsportation	tra
15	15	**Med**ical Care and Health	med
16	16	**Cul**ture and Lifestyles	cul

This seems to be confusing to a certain extent, but is necessary for a good understanding of the writing in the text and in the charts. It facilitates the search for a certain topic not only in this but also in the previous reports where the enumeration is congruent.

A third main piece of transposing work was the careful selection of the group to be questionned in Germany. There was no long-standing, up-to-date file available to identify experts as in the Japanese investigation. Various sources had to be consulted to meet the demands of the given structural characteristics of the survey. The following points had to be considered in order to facilitate the comparison between both countries: assignment of the individuals to one of the Delphi specialist areas had to be guaranteed, a proportioned number of specialists from universities, corporations, non-profit private establishments and governmental departments had to be considered and participation of experts from the old and new Länder had to be planned. For details see the German report (BMFT, 1993, pp. 41 - 46).

Another difficulty in transposing the Japanese Delphi to Germany was that the individual questions had been taken out of context so that contextual aspects of the contents were missing and misunderstandings were possible. Question J/G 16-56 is a good example of the ambiguity of certain questions, in which the Japanese word to be translated "Kapsuru", written in Japanese phonetic script, is obviously "Kapsel" in German ("capsule") but it is unclear what kind of capsule it could be, whether a "Schlafkapsel" (sleeping chamber) or the "Tablettenform" (sleeping pill) was meant. As the term is ambiguous in Japanese and no further information could be gained from the context, it was decided to formulate it unambiguously in German. Internal experts knew of a Japanese project in which an oxygen filled chamber was to be developed to allow the human body to convalesce, so it was assumed that this kind of chamber was meant. Accordingly the translating team formulated the following "An apparatus in the form of a bedchamber is being developed in which a process of rejuvenation takes place during sleep" instead of the version "Development of capsules that make us grow younger while asleep".

This question is also illustrative of the fact that it is generally easier to understand specialist terms written in Japanese characters (Kanji) and not in one of the two syllable scripts Hiragana or Katakana. The Kanji can either be lined up so that each character with its individual meaning describes the functions of the specialist term such as "organic molecular materials" which is unambiguously identifiable as "polymer" or the Kanji are used according to their sound which is very seldom with the modern vocabulary of this case and did not cause further problems.

Kana (Katakana are used in most cases to write foreign words), on the other hand, represent only the sound of the word. As these are usually borrowed foreign words or words newly created which are based on English and adapted to the fact that Japanese does not have any single consonants, it was difficult in many instances to identify these words if they were not generally known, e.g. there were some problems to understand "Rimôto Senshing" as "remote sensing" (J 6-3/ G 5-3, J 6-12/ G 5-12 or J 10-55/ G 9-55) and "Gôsuto Kyansera" as "Ghost Canceller" (J 13-22/ G 12-22).

The specials aspects of the Japanese script have led to considerations about new technologies and their actual development in Japan, for example the fax machine was developed for these reasons. In the Delphi survey, these considerations are reflected in the Japanese formulations of questions J 2-92/ G 2-93 and J 2-97/ G 2-98. Unfortunately, in German, the explicit term "Japanese text" had to be changed for comprehension reasons. In J 2-92/ G 2-93 "Japanese" was simply omitted so that the question only refers to text in general. In J 2-97/ G 2-98 "handwritten Japanese text" was reformulated as "handwriting" although handwritten alphabetic text is not as difficult to identify as handwritten Japanese *Kanji*.

The specialist terms "Bioholonics" (J 11-65/ G 10-65) and "Mechatronics" (J 10-38/ G 9-38), in particular, were legible (written in Katakana) but caused great difficulties as regards content as they were created in Japan and have only become general terms there, so that they cannot necessarily be assumed to be known in German specialist circles. Such terms appear in several questions, e.g. "remote sensing" (J 6-3/ G 5-3, J 6-12/ G 5-12 and J 10-55/ G 9-55), "man-machine-interface" (J 12-37/ G 11-37) or "human-interface" (J/G 16-36) or others that are actually known to the specialists but have not yet appeared in previous translations nor, therefore, in dictionaries and were not traceable in the usual reference books used by the translators. These were partly adopted as English specialist terms if they were already familiar, partly replaced by German equivalent terms, e.g. "virtuelle Realität" (virtual reality) (J 11-48/ G 10-48, J 11-51/ G 10-51 and J 12-21/ G 11-21), "Künstliche Intelligenz" (artificial intelligence) (J/G 3-14, J/G 3-66, J 11-44/ G 10-44, J 11-55/ G 10-55, J 13-55/ G 12-55, J/G 14-34 or J/G 16-3) or "Mensch-Maschine-Schnittstelle" (man-machine-interface) (J 12-37/ G 11-37, J/G 16-36). Terms which were too specialised were given an additional German explanation (e.g. the so-called "Mechatronik" in question J 10-38/ G 9-38). In other cases, paraphrasing was necessary as no single, unambiguous term could be found, e.g. in questions J 10-71/ G 9-71, J 11-47/ G 10-47 and J/G 16-73 the "Schulungssystem für die berufliche Entwicklungsplanung" (Career Development Plan).

Greater difficulties were caused by names such as "Karina-" or "Rankine-Kreisprozeß" (J 8-34/ G 7-34) which could be identified as such but which showed great variation as it is unknown from which language the sounds were taken. This is a general problem with retranslating Japanese texts as the foreign words to be

integrated into Japanese are adapted to the Japanese syllabory which alters their original pronounciation.

Abbreviations, on the other hand, were comparatively easy to identify as they are generally written in Roman letters and represent non-Japanese words, usually from English, e.g. GPS = Global Positioning System, EMT = electromagnetic thrusts or VLBI = Very Long Baseline Interferometry and could therefore be directly determined by specialists. However, the terms cited have such specialised meanings that these cannot necessarily be immediately explained even by specialists without first ascertaining their exact meaning. The same thing is true for "Glutwolke" (nuee ardente) (J 6-77/ G 5-77), in Latin "Ignimbrit", a term which is not often used in Germany where volcanology is not as ubiquitous as in Japan.

New terms, which are not yet unambiguously defined in German such as "Neurocomputer" (J/G 2-31 and J/G 3-60), "Biocomputer" (J/G 3-20) or "Biosensors" (J/G 2-48, J/G 2-49, J/G 3-18, J/G 3-53) etc. are not easy to translate as they describe things that have not yet been defined such as the "in der Luft installierten (brückenähnlichen, rohrförmigen) Korridore" (pipe-like corridors installed in the air similar to bridges) in J/G 15-59 or in question J/G 14-62 "Verkehrssysteme in vertikaler Richtung" (vertical transportation systems) which have five times the capacity of present-day elevators but the same volume and could be used for transportation in skyscrapers. It was just as difficult to translate vague or inexact terms such as "Flugboote" ("flying boats") (questions J 6-10/ G 5-10, J/G 14-29 and J/G 14-43) which referred to a certain kind of "Tragflächenboote" (e.g. hydrofoil or airfoil). As this was not made explicit, there was the danger of an incorrect judgement by the experts (certain kinds of "flying boats" are already existing) so that it was decided to qualify with further information where necessary, e.g parantheses were added in J/G 14-29 and J/G 14-43 but not in J 6-10/ G 5-10 as the emphasis here was on Practical Use and the *type* of hydrofoil was irrelevant for the formulation of the question.

In addition, there were words in the survey which seemed to be unambiguous because they are easy to read and identify as English words in Katakana but whose meaning has been altered in Japanese, in an extended or diminished sense. For example, the meaning of the term "monitoring system" in question J 6-19/ G 5-19

had been altered to include every possible kind of observation system so that it could be translated as "chemical analysis system" in this question.

The examples cited show how important it was for the comprehension of the topics and, therefore, the later judgement of the experts, not just to simply "translate" but to find a terminology corresponding to a generally comprehensible technical vocabulary. The wrong utilisation of terms e.g, the use of understandable but not correct special technical wording, would have made the Delphi questionnaire more open to the criticism of not paying enough attention to the terminology in the eyes of specialists. For this reason, the endeavours to include the advice of internal and external experts, although very time-consuming, paid off in most cases. The technical terms were correctly understood by the interviewees as was shown by the relatively homogeneous answers, even if there were comments about shortcomings or doubts about the accuracy of the translation in some cases (e.g. in questions J 6-55/ G 5-55, J 6-56/ G 5-56, J 6-66/ G 5-66, J 7-17/ G 6-17 and J 10-32/ G 9-32).

Understanding the sense of a question or references mentioned was often more problematic. Among other reasons, this is due to the fact that some things seem inconceivable in Germany (such as the corridors between skyscrapers for example in question J/G 14-59 or the elevator baskets passing each other in question J/G 14-62) as well as the relationships of terms within whole sentences (e.g. coral reefs in question J 6-21/ G 5-21 or in Agriculture, Forestry and Fisheries questions 22 and 49, question 16 in Culture and Lifestyles etc.). Any changes made in translation would not only have distorted the results but also impeded the comparison of individual questions with the original. There are more examples than those cited above. In these cases, attention was paid to formulating the questions as closely to the original as possible even though the resulting sentence sounded clumsy and "Japanese". Several questions, despite all the efforts made, were incomprehensible according to the experts. In these cases, it remains to be seen whether the subjects themselves rather than the formulation of the questions were too much for the experts (restricted specialist knowledge, inconceivability of individual specialist subjects).

Some difficulties existed in translating the defined verbs which mark phases of innovation (see BMFT 1993, p. 35). In German, with its strong verbal structure, it proved difficult in several cases to integrate these into the sentence as the verbal position was already occupied or because the combination of verb and substantives make no sense. In the English translation, this problem was avoided by using nouns such as 'elucidation, development, practical use or widespread use' instead of verbs.

In connection with the entire sense of a question, marked cultural characteristics of Japan were noticeable. An extreme example is the word "Ki" in question J/G 3-69 which can express many feelings and conditions depending on the context but which tends to mean heart, spirit, soul, mind, nature, disposition, feeling or magnanimity. It was decided in this case to translate it with "Ahnung" (presentiment, hunch) as this was close to the intended sense but it must be borne in mind that "Ahnung" describes only a small semantic area of the word "Ki". The appropriate translation of cultural terms has already occupied famous anthropologists (Aoki, 1992).

A further example of cultural characteristics is question J 11-62/ G 10-62 which has as its background a completely different approach to values in society or societal aims. Leisure time in Japan is structured mostly by the employing companies (see, e.g. Cuhls 1993, p. 133) which in many cases offer programmes of enjoyable employment for free time. The above mentioned question, exactly translated, is "Entertainment factories as firms in which staff and visitors can enjoy themselves are widespread. (Systems, in which an identification with the company or institute is expressed, in which one shows this identification, recognises it and has a good time)". As this formulation contains too strong an evaluation, it was translated as follows in the German Delphi questionnaire "Entertainmentfabriken (entertainment factories), die sowohl Firmenangehörigen als auch Besuchern eine Corporate Identity vermitteln, sind weit verbreitet (positiv besetzte Firmendarstellung)" (Entertainment factories which transmit a corporate identity to employees as well as visitors are widespread (positive company presentation)). The desired identification with the company is expressed in Europe and America as the management concept "corporate identity". To indicate the Japanese values involved - which are difficult to comprehend in Europe - the context was filled with the term "common" here which could not, however, be explained in more detail. It was left to the experts to decide whether they believe the creation of a corporate identity using the means identified is technically possible in Germany.

At first sight, attributive terms whose meaning is identical in German and Japanese seemed to be easy to translate, e.g. the phonetically (in Katakana) written "total" (totaru). The direct translation caused great problems as extreme claims appeared, among others a "totally informed society", question J 11-58/ G 10-58, whose totality is contrary to societal goals in Europe. After lengthy discussions among German experts it was decided to retain these extremes as well as the exaggerations ("völlig" (completely), "ultra-..", "super..", "hoch.." (high) etc.) and to leave the judging to the experts. "Epochal" was, however, toned down to "extraordinary". Examples commented upon were questions J 11-58/ G 10-58 and J 8-50/ G 7-50; the latter was particularly controversial as the choice of words seemed to contradict the main natural laws of thermodynamics. This could have been moderated by choosing another attribute but then would not have complied with the Japanese sense which explicitly (and follow-up enquiries confirmed this) requires as an *aim* a "totally (Japanese: totaru=total) loss-free use of energy". Incidentally, the term "Energieverlust" (energy loss) was retained here as "total", which is in general use, but which, physically, according to the laws of thermoclynamics, cannot be a "loss" at all. Strangely enough, some German Delphi respondents rejected to answer to this topic which they perceived as the "perpetual motion", or ticked "never" on the time scale, although the intention of the topic was to avoid all *possible* energy losses "totally". At the same time, these experts accepted the likewise incorrect colloquial terms "energy loss" and "energy generation" in this and in other questions.

Geographical terms were simple to translate. As far as possible, "Japan" was replaced by "Germany" and "Japanese" by "German" (e.g. question J/G 16-61) or no place was given. For example, "Tôkyô Bay" was replaced with "Rhine river" in a question on water quality (J 7-34/ G 6-34) or *German bay* (J/G 14-38) and "Japanese Prefecture" was translated as "German Region" in J 4-12/ G 13-12.

The differences in the geographical conditions between Germany and Japan is a problem of question content on which the translator group had no influence due to the decision to adopt the Japanese questions. For example, there are no active volcanoes in Germany, in general no violent earthquakes and the conditions for agriculture (no wet field farming, question J 10-7/ G 9-7) and fishing (questions J

10-46 to 59/ G 9-46 to 59) are also different. Nevertheless, after a long discussion with German experts, topics connected with these were still adopted directly or

reformulated and not simply omitted (question J 10-6/ G 9-6 was the exception, see below).

The most amusing example for such differences was definitely question J 10-18/ G 9-18 which was translated as follows: "Biomimetic farming aid machines, e.g. small weed removing robots which mimic the movements of helmet shrimps or ducks, or pollination robots copied from bees are used in agriculture". The original Japanese sentence described "weed removing robots which copy the movements of "kabuto ebi or ai gamo..." Every Japanese knows "kabuto ebi", a certain kind of helmet shrimps which are just as well known as "ai gamo", a cross between tame and wild ducks, so that the correct associations were made immediately in Japan whereas hardly anybody in Germany knows in detail how such animals move (waddling).

There were only three questions which could not be asked in Germany. They were not translated at all. One question was on the *widespread use of hybrid rice plants for at least 50 per cent of the total planting in Japan* (J 10-6/ G 9-6). As described above, in most cases, it was possible to replace "Japan" by "Germany", but as there is no cultivation of rice in Germany, no 50 per cent margins exist.

The second omitted topic was J/G 15-86: *Performance of kidney, heart, lung, and other organ transplantation in Japan with a regularity on the order of that in Europe and in North America*. By already comparing with Europe and explaining the regularity of organ transplantations as possible in Europe, it would have made no sense to ask such a question in Germany. The impossibility of organ transplantations in Japan is not due to technical obstacles but the result of cultural attitudes and acceptance (81 per cent of the experts mentioned cultural constraints) as well as institutional hindrances (69 per cent of the Japanese experts).

In the third topic that was left out, J/G 16-52 *on the development of cosmetics that enhance the metabolic function of the stein and are specially suited to Japanese skin*, the word "Japanese skin" could not easily be transposed by "German skin" because in Germany and the USA this kind of cosmetics already exists. In Japan, it is supposed, that the Japanese skin is different from other, especially "white skin" and thus medicine and cosmetics from foreign countries cannot be used in Japan without further investigation. The topic is thus irrelevant for Germany. The questions were not translated into German and not included in the comparison but in order not to mix up the chronological order, their number remained empty in the questionnaires together with an explanation, that the text was left out.

Furthermore, the Japanese Delphi team noticed that question 2/60 which was still asked in both rounds of the survey was already realised (NISTEP was approached by a company that already developed the technology some years ago). Thus, the Japanese Delphi team did not include the topic into their report (NISTEP, 1992). In the German report (BMFT, 1993), it was still analysed, but for the comparison this question had to be excluded. Hence, the number of compared topics in this report is 1,146 although the questionnaires consisted of 1,150 in Japan (1,149 in the report) and 1,147 topics in Germany.

Despite all the problems mentioned, and others, the translation seems to have been successful in general as the answers and comments of the experts prove. A few exceptions, whose meaning was not unambiguously defined, remain problematic. The translation was very time consuming as experts had to be consulted repeatedly. The majority of the technical questions was unproblematic but individual ones required extensive research. On the one hand the questions were supposed to comply with the Japanese originals, on the other they were not supposed to sound "too Japanese". Despite this, they should still be comprehensible which caused the most problems where cultural terms and contexts were involved.

Summarizing, there were three major difficulties in transposing the Japanese Delphi approach to Germany. One was resulting from the different language and peculiarities of the Japanese language and culture. This can be avoided in the future by jointly developing a survey questionnaire but was - for reasons of time limitations and the later start in Germany - not possible this time.

The change in the order of the technological areas could be solved by statistical means. The third difficulty, to match the Japanese sample of experts, was a problem of unexperience in the application of the Delphi method and the lack of a well-established data-bank on the German side, but as described in chapter 1.3 was solved to the satisfaction of both research teams.

1.5 Outline of Survey Parameters and Data Processing for the Comparison

In Japan's Fifth Technology Forecast Survey Report and Germany's Delphi Report, the upper row shows the number of respondents to the first questionnaire, the centre row shows the number of respondents to the second questionnaire, and the lower row shows only the number of respondents who answered "High" in the degree of expertise column in the second questionnaire (Figures 1.5-1 and 1.5-2). In this report, we made a comparative analysis of the Japanese and German technology forecast results based on the results from all respondents to the second questionnaire.

In making the comparative analysis, we indexed each question item to quantify the results of the Japanese and German technology forecast surveys. Below is an explanation of what is contained in each question item and how we indexed the question item and calculated the forecasts realization time. For all variables only the responses given by respondents who have expertise "High", "Middle" or "Low" on the topic in question are considered in the analyses. Responses by respondents who indicated "None" to the degree of expertise have not been considered.

1.5.1 Degree of Expertise

For the degree of expertise we asked respondents to indicate the degree of specialist knowledge they have related to the topic in question by selecting one of the four steps of "high", "medium", "low" and "none". As can be seen in Figure 1.5-1 and 1.5-2, the Japanese and German reports show the result for each step as a percentage of the total number of respondents. Only responses given by respondents who indicated "low" or above the degree of expertise have been handled as effective responses.

Figure 1.5-1: Example of the Japanese Report

Figure 1.5-2: Example of the German Report

Special attention is needed to define the number of effective responses. In this report, two concepts were possible which have special analytical meanings. In the *expertise* concept only those responses with useful answers were taken as 100 per cent. Those experts who indicated no expertise in the particular topic have been handled as non-effective responses. It can well be the case that this group is small (but very knowledgeable) and most other experts could not answer to that topic (for examples see below). In the "*expert knowledge*" concept (see chapters 2.1, 3.1, 3.2 and 3.3) all experts are included (100 per cent). In this case, it is analysed whether general expertise in the country is low or high for the topic irrespective of the effective answers. The two concepts may differ a lot if many experts could not answer.

Given that the number of respondents who chose "high", "medium", "low", and "none" for each of the questions is represented by N_{eh}, N_{em}, N_{el} and N_{en}, respectively, the *expertise* index I_e can be calculated as follows:

$I_e = 100\ (4 \times N_{eh} + 2 \times N_{em} + 1 \times N_{el}) / 4 \times N_{eff}$
where the number of effective responses is $N_{eff} = N_{eh} + N_{em} + N_{el}$.

For the *expert knowledge* the following formula applies accordingly:

$I_k = 100\ (4 \times N_{eh} + 2 \times N_{em} + 1 \times N_{el} + 0 \times N_{en}) / 4 \times N_{eff}$
where the number of effective responses is $N_{eff} = N_{eh} + N_{em} + N_{el} + N_{en}$.

Let us compare the two concepts by an example. In the Japanese survey, only 16 per cent did not answer item J/G 15-4. Therefore, the two concepts yield about the same results: expertise is $I_e = 46$ and experts' knowledge $I_k = 39$. For J/G 1-11 however, 64 per cent or, absolutely, 126 experts were not prepared to provide an answer, whereas 71 experts had high, medium or low expertise. In this case, *expertise* is $I_e = 49$ but *expert knowledge* $I_k = 18$. In this report, the *expert knowledge* measure is used in chapter 2.1, 3.1, 3.2 and 3.3.

1.5.2 Degree of Importance

The degree of importance expresses the impact of each topic on the progress of science and technology or on the economy or on the society and respondents were asked to choose one of the four steps of "high", "medium", "low" and "unnecessary". The Japanese and German technology forecast survey reports show the result for each step as percentage of the total number of respondents.

In this report, "high", "medium", "low", and "unnecessary" were given values of, respectively, "4", "2", "1", and "0", and responses were indexed from a maximum of 100 (in the case where all respondents chose "high") to a minimum of 0 (in the case where all respondents chose "unnecessary"). Given the number of respondents who chose "high", "medium", "low", and "unnecessary" for each of the questions is represented by N_{ih}, N_{im}, N_{il}, and N_{in} respectively, the importance index I_i can be calculated as follows:

$$I_i = 100\ (4\times N_{ih}+2\times N_{im}+1\times N_{il}+0\times N_{in})/\ 4\times(N_{ih}+N_{im}+N_{il}+N_{in})$$

1.5.3 Time of Realization

For the time of realization the years 1991 to 2020 were divided into six selections of five-year blocks, and also a selection was made for those that would not be realized by 2020, and respondents were asked to choose from these selections. Respondents could also choose "do not know", so there are cases where respondents have given answers for the degree of importance etc. but not for the forecasted realization time.

To calculate the forecasted realization time the median was used. That is, all responses were listed in the order from the earlier forecasted realization time, then, the forecast of the responses were taken that were at the halfway point of all responses. However, in the questionnaire, selections were divided into five-year blocks, so judging that there would be an even spread of responses over five years within the same block. Similarly, the forecast years for responses were calculated that were at the quarter point and the three-quarter point of all the responses to show the convergence of all responses.

It is impossible to give a numerical value to the time of realization for responses of "will not be realized by 2020", however, here a hypothetical realization year was calculated by replacing responses of "will not be realized by 2020" with "2021-2025". There are two reasons for this. First, when calculating the average time of realization in the technological area, if we were to exclude "not realized", there would be a difference between Japan and Germany in the topics for which "not realized" is forecasted, so naturally there would also be a difference in the remaining topics, and there would no longer be any commonalty in the topics used to calculate average values. Second, when making comparisons between technological areas, if we were to calculate average values after excluding areas in which many topics are assessed as "not realized", such as the area of Particles, the realization time would suddenly be much earlier, and the report would not properly reflect the fact that there are many topics of essentially long-term technology.

The following is the calculation method adopted for the forecast year (one-half value), the one-quarter value (lower quartile) and the three-quarter (upper quartile) value. In the calculation, forecast blocks are represented by P_i, the number of respondents by n_i, and the total number of respondents for the block in question and all earlier blocks by m_i.

P_1 (1991-1995): n_1 answers, $m_1 = n_1$
P_2 (1996-2000): n_2 answers, $m_2 = n_1+n_2$
P_3 (2001-2005): n_3 answers, $m_3 = n_1+n_2+n_3$
P_4 (2006-2010): n_4 answers, $m_4 = n_1+n_2+n_3+n_4$
P_5 (2011-2015): n_5 answers, $m_5 = n_1+n_2+n_3+n_4+n_5$
P_6 (2016-2020): n_6 answers, $m_6 = n_1+n_2+n_3+n_4+n_5+n_6$
P_7 (2021-2025) (not realized): n_7 answers, $m_7=N$
$N = n_1+n_2+n_3+n_4+n_5+n_6+n_7$
$m_0 = 0$

The respondents on the 1/4, 1/2 and 3/4 points are calculated as follows:

$X_{1/4}$ = (N+3)/4
$X_{1/2}$ = (N+1)/2
$X_{3/4}$ = (3×N+1)/4
E.g., The forecast year ($t_{1/2}$) corresponding to $X_{1/2}$ is calculated as follows, given in the block P_i.

$$t_{1/2} = 1990+5\times(i-1)+5\times(X_{1/2}-m_i-1)/(n_i+1)$$

1.5.4 Degree of Certainty

For the degree of certainty, respondents were asked to indicate the certainty (confidence) they felt when answering the realization time. They were asked to choose one of the three steps "high", "medium" and "low". The Japanese and German technology forecast survey reports show the result of each step as a percentage of the number of respondents.

High: The range of the forecasted realization time of the topic is "about three years or less" (in the Japanese questionnaire) or is "more precise than the five-year interval" (in the German questionnaire).

Medium: The range of the forecasted realization time of the topic is "about five years or less" (Japan) or "corresponds to the five-year interval" (Germany).

Low: The range of the forecasted realization time of the topic "exceeds five years" (Japan) or "exceeds the five-year interval" (Germany).

As for the indexing the degree of certainty, given that the number of respondents who chose "high", "medium", or "low" for each question is, respectively, N_{eh}, N_{em} and N_{el}, the degree of certainty is

$$I_c = 100\ (2\times N_{ch}+1\times N_{cm}+0\times N_{cl})/\ 2\times(N_{ch}+N_{cm}+N_{cl})$$

This index gives quadratic weights as above but in this case, there are only three categories of possible answers. The responses are indexed from a maximum of 100 (in the case, where all respondents chose "high") to a minimum of 0 (in the case that all respondents chose "low"). This index is symmetric for mathematical reasons. An index value of zero does *not* mean that there is *no* certainty but rather that *all* respondents consider certainty as being *low*.

1.5.5 Necessity of International Joint Development

Respondents were asked to indicate their thoughts about the necessity of international joint development for a better or earlier realization of the topics by choosing one of the four steps of "high", "medium", "low", or "none". The Japanese and German technology survey reports show the result of each step as a percentage of the number of respondents.

High: Cannot be realized without international joint development.

Medium: International joint development is not essential but far better results would be obtained through international joint development.

Low: International joint development is not necessary in particular, but there is a possibility of international joint development.

None: There is no need of international joint development.

The method of indexing the necessity of international joint development is the same as that for the degree of importance. Given that the number of respondents who chose "high", "medium", "low", and "none" for each of the questions is N_{jh}, N_{jm}, N_{jl} and N_{jn} respectively, the index for the necessity of international joint development I_j can be calculated as follows:

$$I_j = 100\ (4\times N_{jh}+2\times N_{jm}+1\times N_{jl}+0\times N_{jn})/\ 4\times(N_{jh}+N_{jm}+N_{jl}+N_{jn})$$

1.5.6 R&D Level

Since the Japanese and German questions for the R&D level were different, it is impossible to compare overall absolute values. We are, however, able to compare the index for the Japanese "Japan is more advanced" and that for the German "Japan is at the forefront".

(1) Japan

For the comparison of the current R&D level between Japan and other countries, respondents were asked to choose one from among the four choices of "Japan is more advanced", "equivalent", "other countries are more advanced" and "don't know", and in the Japanese technology forecast survey report, the result for each choice is shown as a percentage of the number of respondents.

In this report, "Japan is more advanced", "equivalent" and "other countries are more advanced" were given values of respectively "2", "1", and "0" for certainty, and responses were indexed from a maximum of 100 (in the case where all respondents chose "Japan is more advanced") to a minimum of 0 (in the case where all respondents chose "other countries are more advanced"). Given that the number of responses of "Japan is more advanced", "equivalent", and "other countries are more advanced" for each of the questions is represented by N_{lj}, N_{le} and N_{lo} respectively, the index for " Japan is more advanced" I_{lj} can be calculated as follows:

$$I_{lj} = 100\,(2\times N_{lj}+1\times N_{le}+0\times N_{lo})/\ 2\times(N_{lj}+N_{le}+N_{lo})$$

(2) Germany

In Germany's case, respondents were able to give multiple responses (up to four choices if they judged several countries as equal) as to which country's technology they believe is at the forefront from among "USA", Japan", "other countries" and "Germany" (respondents who were unable to make a judgement were asked to choose "don't know"). "Other countries" includes all countries other than the United States, Japan and Germany; e.g., if respondents thought that the United States and France led the world in a certain topic, they would choose "USA" and "Other countries". In the German technology forecast survey report, the result for each choice is indicated as a percentage of the number of effective respondents. Given that the number of responses of "USA", "Japan", "Other countries" and "Germany" for each of the questions is represented by N_{lu}, N_{lj}, N_{lo}, and N_{lg} respectively, the index for "Japan is at the forefront" I_{lj} can be calculated as follows:

$$I_{lj} = 100N_{lj} / (N_{lu}+N_{lj}+N_{lo}+N_{lg})$$

The choices of "USA", "Other countries" and "Germany" are at the forefront were indexed in the same way.

1.5.7 Constraints

For constraints, respondents had to indicate whether there were any problems (or whether they expected any problems) in the realization of the topic. They were asked to choose a maximum of two from among eight choices of "technical constraints", "institutional constraints", "cultural constraints", "constraints in costs", "constraints in funding", "constraints in fostering or securing human resources", "constraints in the R&D system", and "other constraints". In the Japanese and German reports, the results for each choice are shown as a percentage of the number of effective respondents.

Technical constraints:	Various technological factors, which are difficult to resolve, are expected to hinder the realization of the topic.
Institutional constraints:	The restrictions placed by law and regulations or unimproved standards or requirements are expected to hinder the realization of the topic.
Cultural constraints:	The sense of values of society, cultural and climate factors or other similar factors are expected to hinder the realization of the topic.
Constraints in costs:	The difficulty of reducing costs for reinforcing market competitiveness or for opening up markets is expected to hinder the realization of the topic.

Constraints in funding:	Insufficient funding is expected to hinder the realization of the topic.
Constraints in fostering or securing human resources:	Inadequate fostering or securing of human resources is expected to hinder the realization of the topic.
Constraints in the R&D system:	Inadequate interactive co-operation between research organisations or researchers, or inadequate consolidation of other R&D systems are expected to hinder the realization of the topic.
Other constraints:	Other factors are expected to hinder the realization of the topic.

In this report, we utilized the percentages directly as the index so that both index and percentage may appear in the figures. Given that the number of responses of "Technological constraints" is represented by N_{pt}, then the index for technological constraints I_{pt} is:

$$I_{pt} = 100N_{pt}/ N_{eff}$$

Indices for other items were calculated in the same way.

Basic Macro Comparison

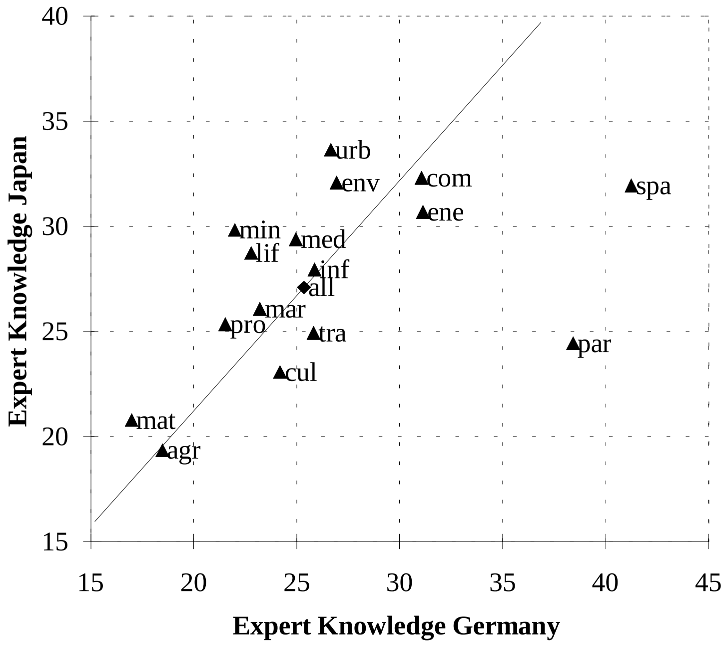
In this chapter, the degree of the respondents' knowledge and of importance, the expected time of realization, the degree of the statement's precision, the necessity of international co-operation, the current level of research and development and the stated constraints on the realization of the specific technology are compared, all of which were asked for in the Japanese as well as in the German Delphi survey. In the first figure, a comparison is made between Japan and Germany for all topics ("All") and the 16 technological areas. In the second, all questions in the order of their innovation or development phase (Elucidation, Development, Practical Use, Widespread Use) are compared.

2.1 Expert Knowledge

The overall self-estimation of the experts' knowledge is around 25 index points and is somewhat higher in Japan than in Germany.

In most of the technological areas, a higher rate of expert knowledge was estimated in Japan but the differences are negligible. In Figure 2.1-1, the drawn line connects the origin with the average "All" and must not be mixed up with the also possible diagonal which would represent equal ratings in both countries. For Energy (ene), Agriculture, Forestry and Fisheries (agr), Communications (com), Transportation (tra) and Culture and Lifestyles (cul), there are hardly any differences (less than 1 index point) in the self-assessment of the Japanese and German experts' knowledge. Only in Life Sciences (lif), Mineral and Water Resources (min) and Urbanization and Construction (urb) does the estimated knowledge of the Japanese participants exceed that of the Germans by 5 index points or more which might be due to the greater number of "Japanese-style questions" in these areas. As the questions were developed in Japan, there are some topics which are not relevant in Germany and, therefore, no general experts for these topics are available.

Figure 2.1-1: *Japanese-German comparison of expert knowledge per technological area (the drawn line passes through the origin and the overall average value)*



In Life Sciences, for example, questions dealing with *biomimetic electrical circuits* (J/G 3-56) or *materials similar to organisms* (J/G 3-57), which, in the German science community, are more dealt within the traditional areas of electronic and material sciences than biology, were not answered by the more biology-oriented scientists asked in this area.

The same can be argued in the field of Mineral and Water Resources (min), in which no "real expert" could be found at all for some of the detailed questions, e.g. in question 3: *Practical use of a reduction method in aluminium smelting instead of using electrolysis*, 4: *Practical use of processes that apply magnetic force as non-ferrous metal casting methods*, 9: *Development of systems that apply laser separating methods as new refining methods for rare metals*, 10: *Practical use of technology for recovering helium from air, spurred by the rising demand for helium and depletion of other helium sources* or 28: *Significant reduction in the loss of human lives by virtue of improved technologies for forecasting landslides and landslips* (all questions from J 7, G 6).
In the field of Urbanization and Construction (urb), in most cases, architectural

specialists were asked to answer the questions in Germany. Due to their specialisation, they were not able to answer questions concerning *facilities or other construction items in space* (J 12-13/ G 11-13) or *manned laboratories on Mars* (J 12-14/ G 11-14). Those topics dealing with space, psychology, electronics or energy are not (yet?) considered relevant to construction R&D and, therefore, neglected.

German experts evaluate the degree of their expertise considerably higher in the fields of Particles (par) and Space (spa) (see Figure 2.1-1). On the one hand, this reflects the German R&D level, which is assumed to be higher than the Japanese. On the other hand, in the German study, only a few but highly knowledgeable experts were approached. For the Japanese Delphi survey, only one questionnaire existed for both, Space and Particles, so that either the Space or the Particles' section experts answered the questions. Therefore, highly knowledgeable experts share a relatively smaller percentage than in Germany where the experts of the fields Space and Particles were approached separately.

The explanation may lie in a different selection of experts in the German Delphi forecast. In all fields, publicly available databases such as "VADEMECUM deutscher Lehr- und Forschungsstätten" and "Hoppenstedt Handbuch der Groß- und mittelständischen Unternehmen" (for details see BMFT 1993, pp. 41 ff.) were consulted. In these areas, the scientific community is very closed and well-documented and only a few but highly knowledgeable experts responded. In the case of Particles, only 25 experts (128 were approached) responded in the first round, of whom only 22 answered in the second round. In the field of Space, the smallest number of experts was identified (63 persons) to participate in the first round. Therefore, the number of participants was increased by an additional search for experts in handbooks on space. As a result, an additional 77 experts could be identified, who were working in the very limited technology area of Space. Again, only 33 persons in the first and 29 experts in the second round answered the questionnaire. These persons seem to be "real experts", which means that the final German sample is constructed of very experienced people, but experts with a lesser reputation in Space and Particles could not be motivated to respond.

One may read Figure 2.1-1 in a different way. The scales for average expert knowledge range from an index below 20 up to 40. This means that, in both nations, the knowledge base per technology area is quite different, but differs in a similar way (see the drawn line). In Materials and Processing and Agriculture, Forestry and Fisheries, either fewer persons can answer all related topics with a high degree of knowledge or their average knowledge is lower than in other areas or both. The areas of Energy, Communications and Space are known best in both countries (index above 30 in both countries), meaning that more respondents answered the related topics with a high degree of expertise or they have a higher-estimated knowledge than the experts of other fields.

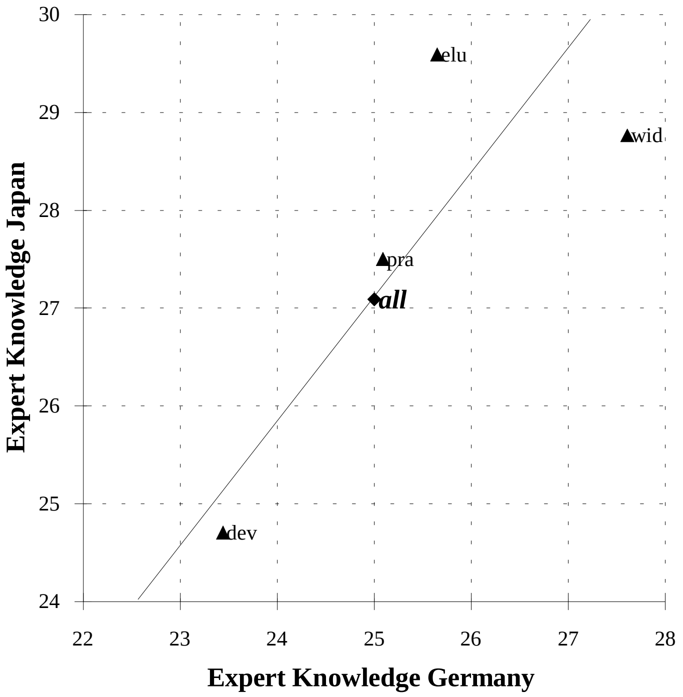
Technology development progresses in phases. These are defined as *Elucidation* (elu) which means that a phenomenon or principle is theoretically explained, *Development* (dev) which concerns experimental development or the construction of a prototype, *Practical Use* (pra) when the possibility and productivity of a product's or technology's application is already proven and *Widespread Use* (wid) of developed products and technologies under market conditions.

These technological phases also define the maturity of technology (see chapter 1.3). However, the distribution of the stages over the 16 areas differs considerably.

Comparing the expert knowledge of all the participants in the Japanese and German Delphi reports according to development phases (Figure 2.1-2), there are very few differences at all (of course, the total average in Japan is about 2 points higher; see above). The deviation in Development and Practical Use is negligible. Only for Elucidation, can a slight difference from the average be noticed, which may result from the priority setting in the Japanese questionnaire but allows no deeper interpretation. On the contrary, it could be a counter-argument for the generally stated thesis that Japan has more experts for application research (pra, wid) and less for basic research (elu). The opposite is the case: German experts claim relatively more knowledge in topics that are candidates for Widespread Use.

One should note that everything was done to adapt the structure of the Delphi experts in Germany to the Japanese structure by age, sector of employment and other factors. While this was achieved overall (see BMFT, pp. 47-61), some special distributions still remain. In Germany, 41 per cent of the respondents are from the enterprise sector, whereas the figure is 38 per cent in Japan. This may contribute *in*

Figure 2.1-2: *Japanese-German comparison of expert knowledge by innovation phases (the drawn line passes through the origin and the overall average value)*



favour of German experts to the 2 index point margin for expert knowledge in widespread technologies. Industrialists may claim higher knowledge for already applied technology.

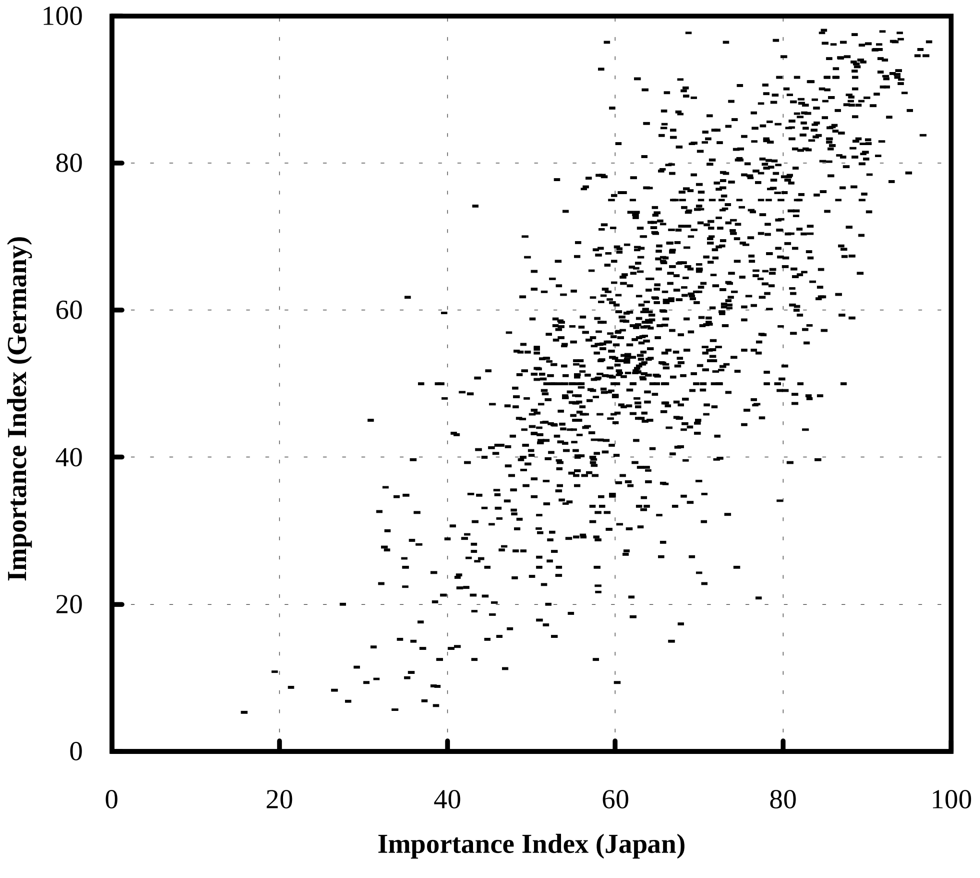
Again, in both nations, the rank order in knowledge distribution is the same: best known are future trends in the very basic and the well-established stage, innovative trends related to first practical use are fair, and development trends are most difficult to assess.

To summarise the results of comparing Japanese and German participants' expertise, no major difference could be found on the macro level if peculiarities in the sample of experts in some fields are taken into account.

2.2 Importance

There is a positive correlation in Japanese and German experts' assessment of importance (Figure 2.2-1). That is, generally, technology which is rated highly important by Japanese experts is also rated highly important by German experts.

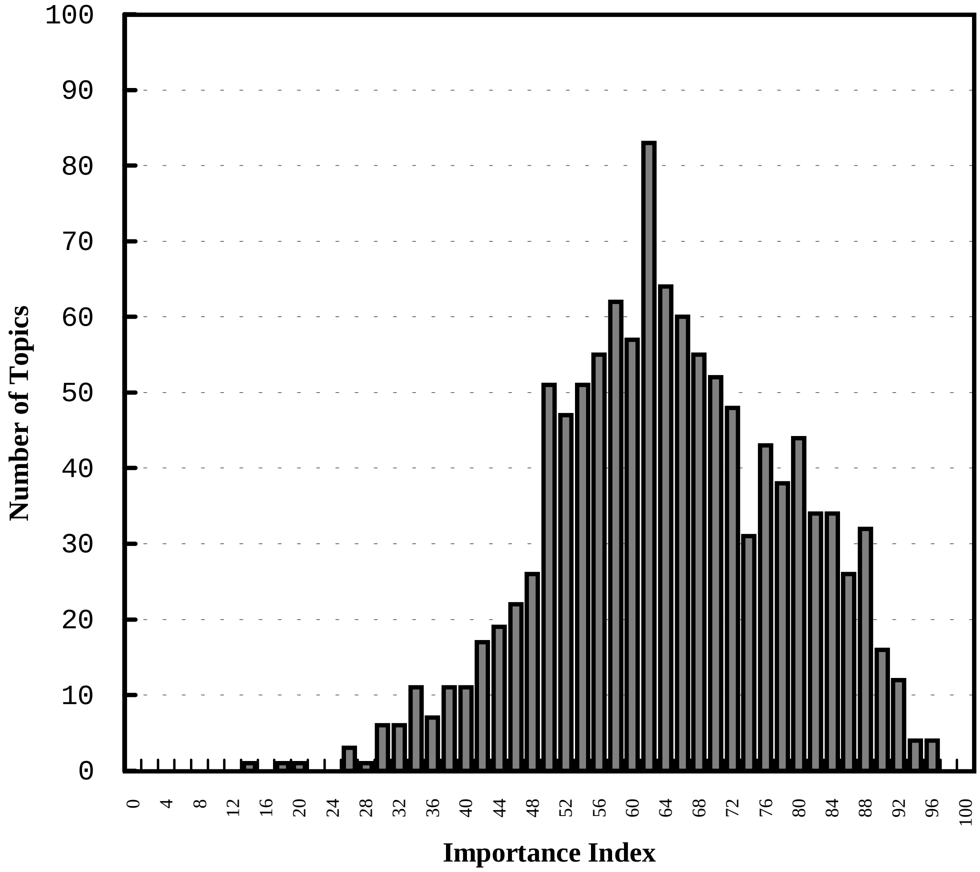
Figure 2.2-1: Comparison of the Japanese and German importance of all the topics



The average importance index for all topics is 65 in Japan and 59 in Germany. Japanese experts tended to rate the importance as slightly higher than their German counterparts, but the difference between the two is not particularly large.

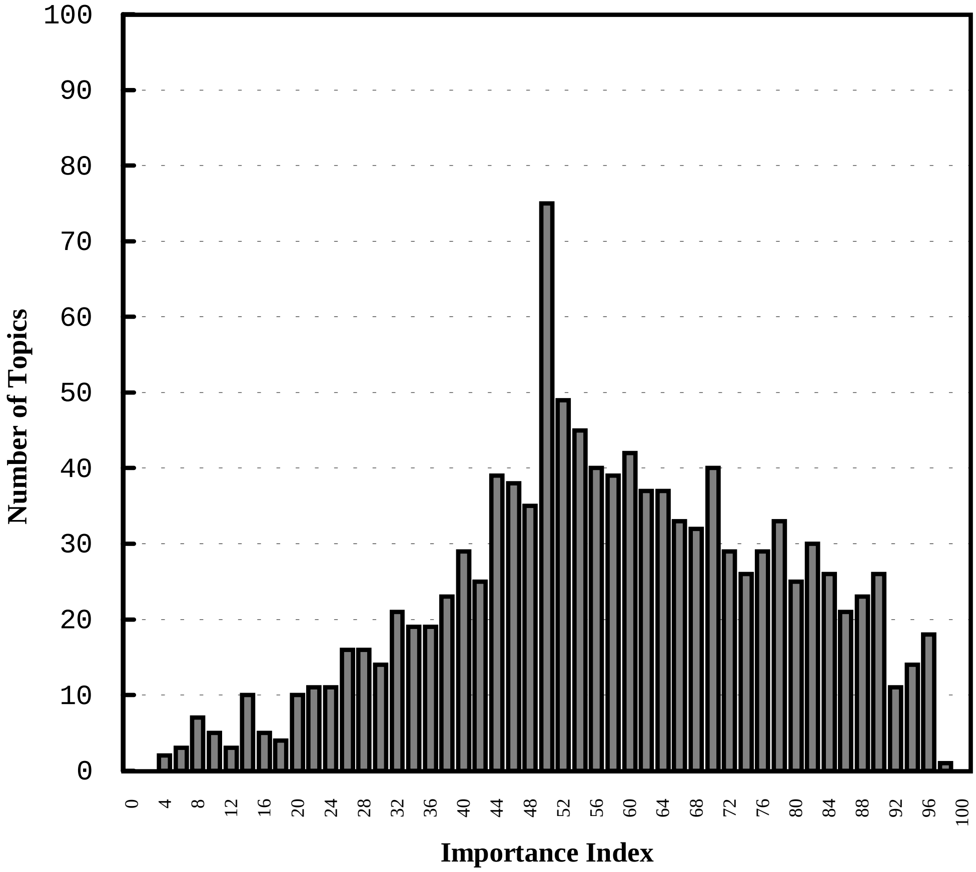
Considering that the topics used in the German survey were prepared by Japanese experts premised on Japanese science and technology and socio-economic conditions, the difference is indeed slight. This is a good indication that today's science and technology has an international universality, and that in industrialised countries, such as Japan and Germany, science & technology and socio-economic conditions are, in general, closely linked.

Figure 2.2-2: *Distribution of important topics (Japan) (All topics are classified every 2 index points)*



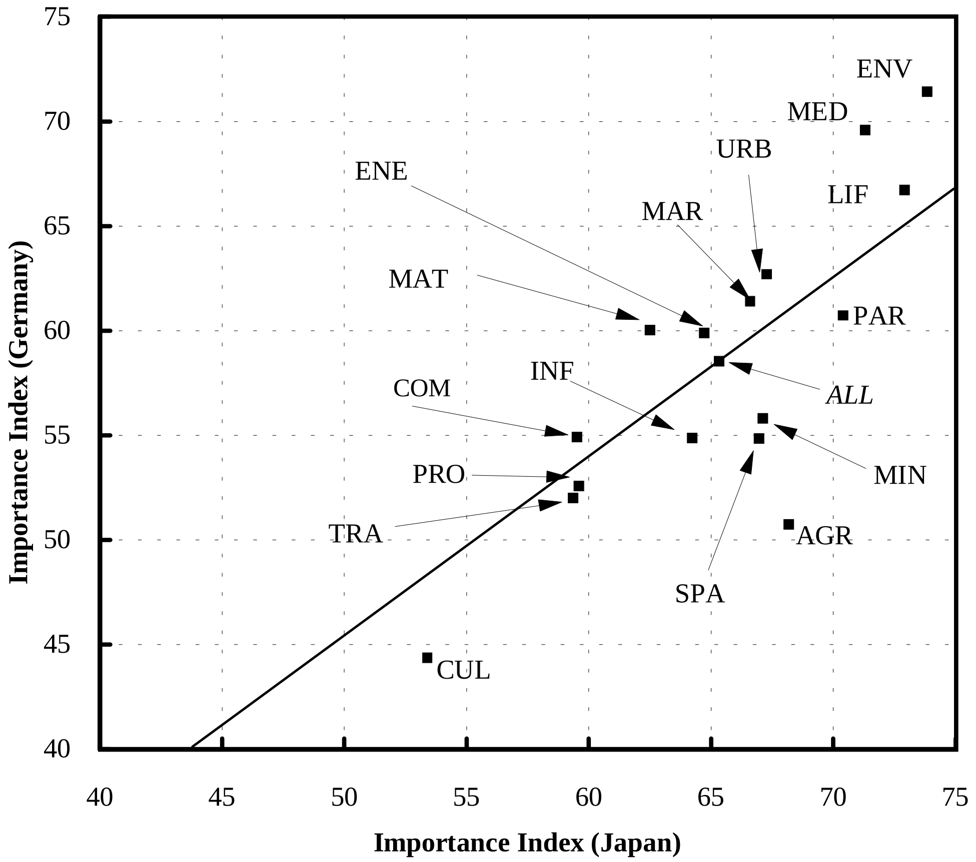
The distribution of importance ratings for Japan and Germany is shown in Figure 2.2-2, and in both, the distribution is bell-shaped centring on the average value. The distribution for Japan is sharp and concentrated in a fairly narrow importance range, while that for Germany is flat and is in a much broader range. In the German survey, there were more topics with very high or very low importance rating than in the Japanese survey. The fact that the topics were drawn up in Japan is seen as the reason for this difference (see chapter 4.2).

Figure 2.2-3: Distribution of important topics (Germany) (All topics are classified every 2 index points)



The Japanese and German average importance indices for the technological areas are shown in Figure 2.2-4. The solid line in the figure passes through the origin and the overall average value, and distances from this line show the relative deviation from the average evaluations in Japan and Germany.

Figure 2.2-4: *Comparison of the Japanese and German importance per technological area (The drawn line passes through the origin and the overall average value)*



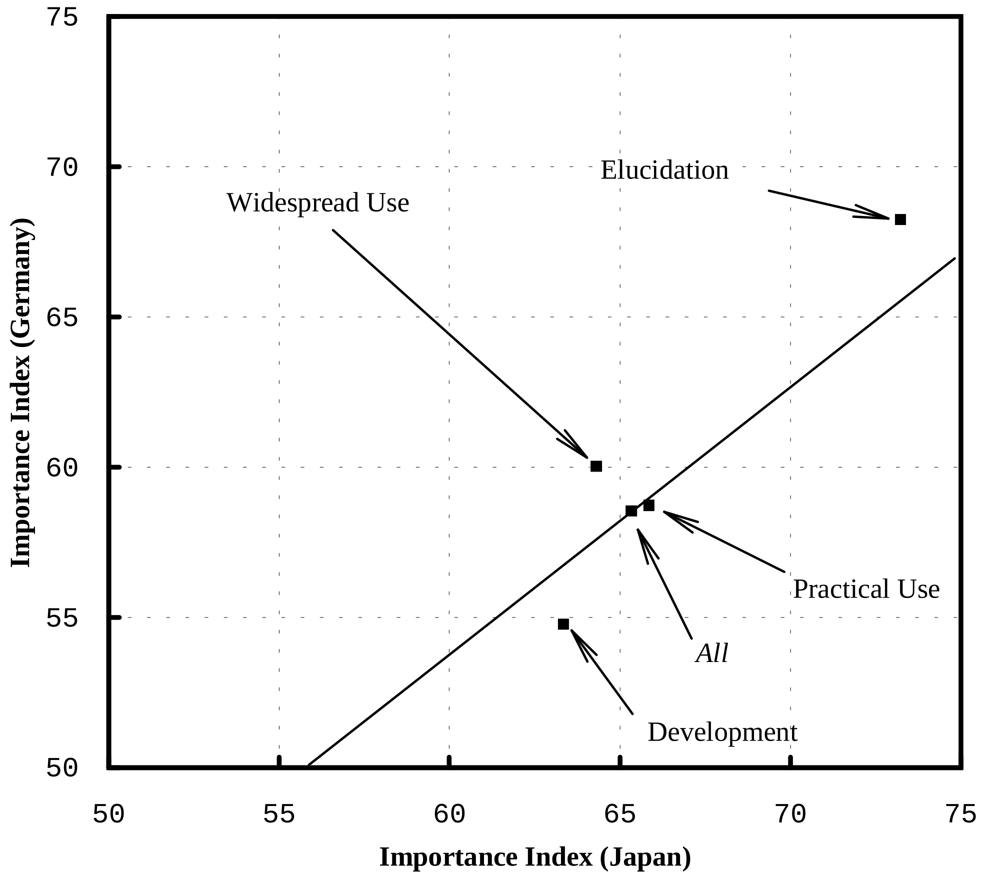
There was conformity between the Japanese and German surveys in ratings for importance in the aspect that Environment (env), Life Sciences (lif) and Medical Care and Health (med) were evaluated as the three most important technological areas while Culture and Lifestyles was rated of low importance in both surveys.

There was a significant difference between the two surveys in the area of Agriculture, Forestry and Fisheries (agr). In the Japanese survey, the importance of this technological area was rated above the overall average, whereas in the German survey, its importance was rated second lowest. The reason for this is that there was considerable difference between the two surveys in the importance rating for fisheries-related topics, which account for about 20 per cent of the topics in the Agriculture, Forestry and Fisheries (agr) area. Fisheries- related topics include e.g., the *practical use of technologies for constructing seaweed "pastures" in undeveloped areas* *such as sandy beaches and estuaries to exploit the potential productivity of marine organisms* (J 10-50/ G 9-50, evaluated in Japan: 66, Germany: 15), the *practical use of selective fishing methods for catching desired size and species of fish and inductive fishing for catching in desirable water area through the development of technologies that are able to control the behaviour of a shoal of fish* (J 10-56/ G 9-56, evaluated in Japan: 60, in Germany: 9), or the *widespread use of super labour-saving fishing boats designed to automate a series of operations from searching for shoals of fish, dragging and lifting nets, to sorting fish by size and storing them consequently allowing the crew to devote only to monitoring* (J 10-57/ G 9-57, evaluated in Japan: 57, Germany: 13).

The fact that greater importance is placed on Particles (par) and Space (spa) by Japanese experts can be thought of as a manifestation of the difference between Japan and Germany in large-scale science and technology. Although the importance ratings for the three areas of the *advanced technology*, which are defined as Materials and Processing (mat), Information and Electronics (inf) and Life Sciences (lif), are not in great distance from the solid line, the fact that Japan give a higher importance rating to Information and Electronics (inf) and Germany gives a higher evaluation to Materials and Processing (mat) is thought to reflect the different areas of technological strength of the two countries. And while there is little difference in the three *infrastructure areas*, which are defined as Urbanization and Construction (urb), Communications (com) and Transportation (tra), German experts estimate a slightly higher importance in the fields of Urbanization and Construction (urb) and Communications (com) than their Japanese counterparts.

The importance by technological stages is shown in Figure 2.2-5. Both Japanese and German experts rate Elucidation stage topics as the most important. This is because in both, the Japanese and German surveys, topics in Life Sciences (lif) and Environment (env), which are rated highly important, account for 61 per cent of all topics in the Elucidation phase. On the other hand, of the four stages, Development was rated the least important by both, Japanese and German experts. This shows that the opinions of experts regarding the importance rating tended to be divided, as there are considered to be many choices for technological development in the Development stage, where elucidated principles are linked to Practical Use. Overall,

Figure 2.2-5: *Comparison of the Japanese and German importance by innovation phases (The drawn line passes through the origin and the overall average value)*

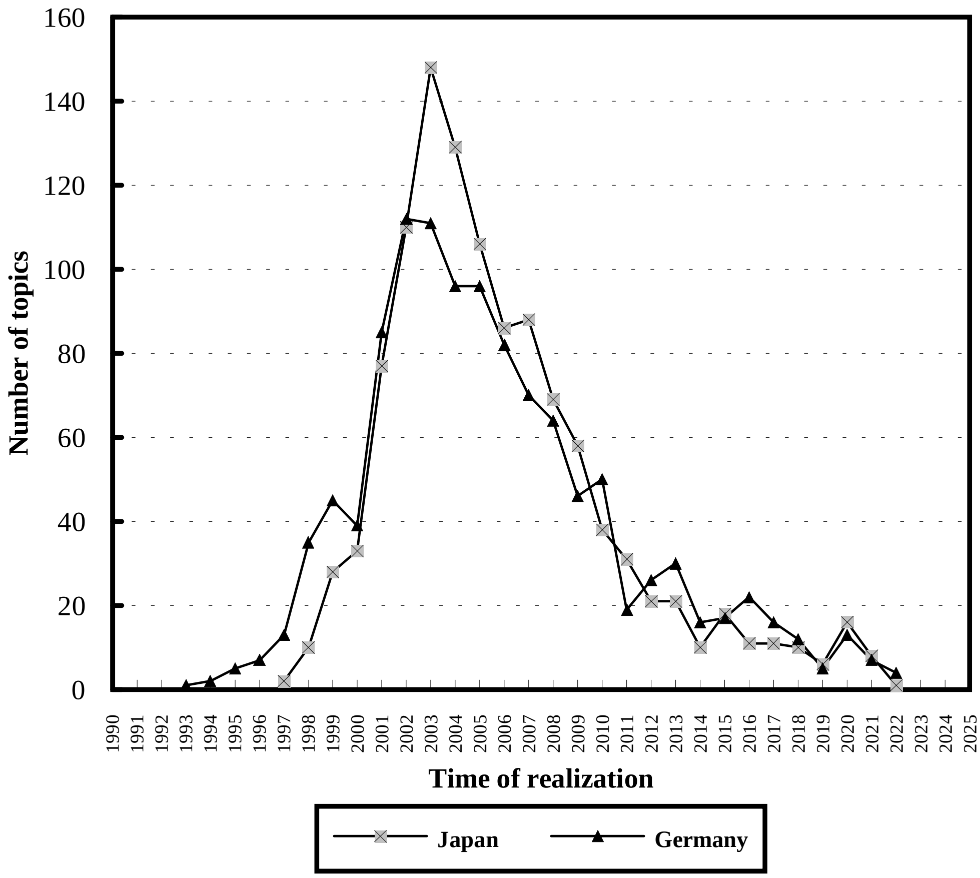


there was close conformity in the Japanese and German ratings of importance in the various technological stages.

2.3 Time of Realization

There was agreement between the two surveys in the average value for the realization time of all 1,146 topics with both Japan and Germany recording 2006. The distribution of the individual topics into the forecasted realization years (Figure 2.3-1) shows a bell shape for both surveys peaking in 2003-2004. In the Japanese survey, more topics were included in the block between 2002 and 2008, which is roughly in the centre of the 30-year realization period from 1991 while the German experts estimated more topics in the realization times of earlier and later blocks.

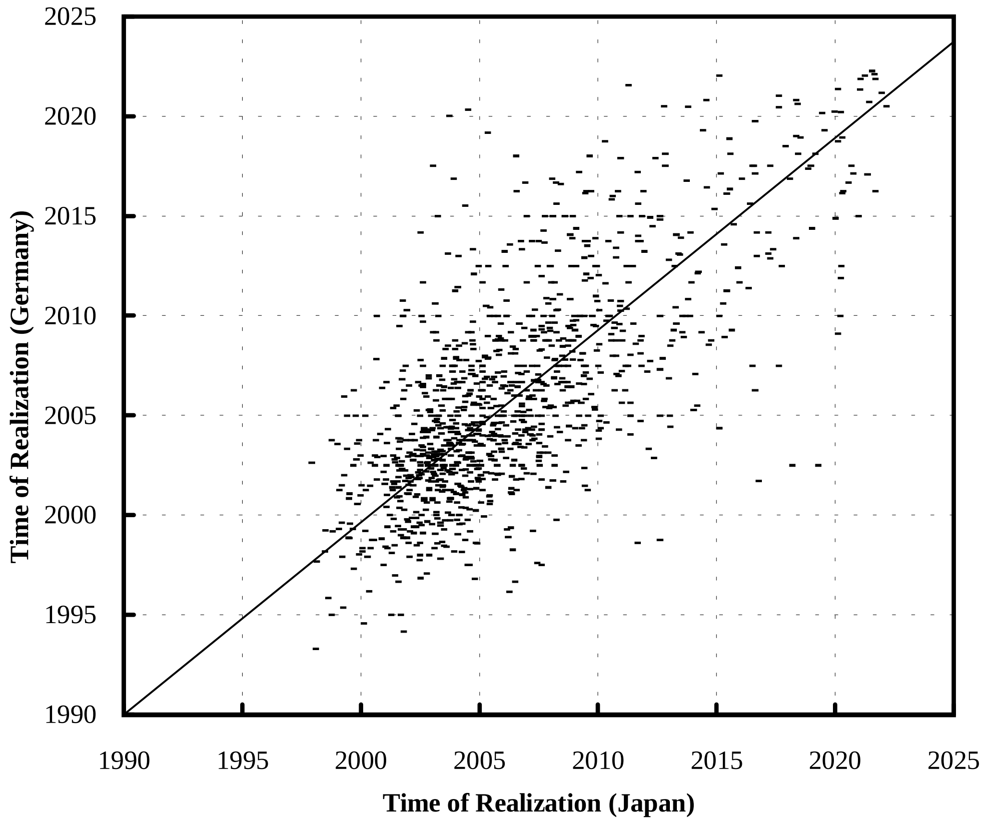
Figure 2.3-1: Distribution of the number of topics per forecasted year of realization



That is, Japanese forecasts tended to be concentrated around the average value more than the German forecasts. This is proven by the fact that in the two years on either side of the average value of 2006 (2003-2009), there are 520 topics in the Japanese survey (45.4%), but only 432 topics in the German survey (37.7%).

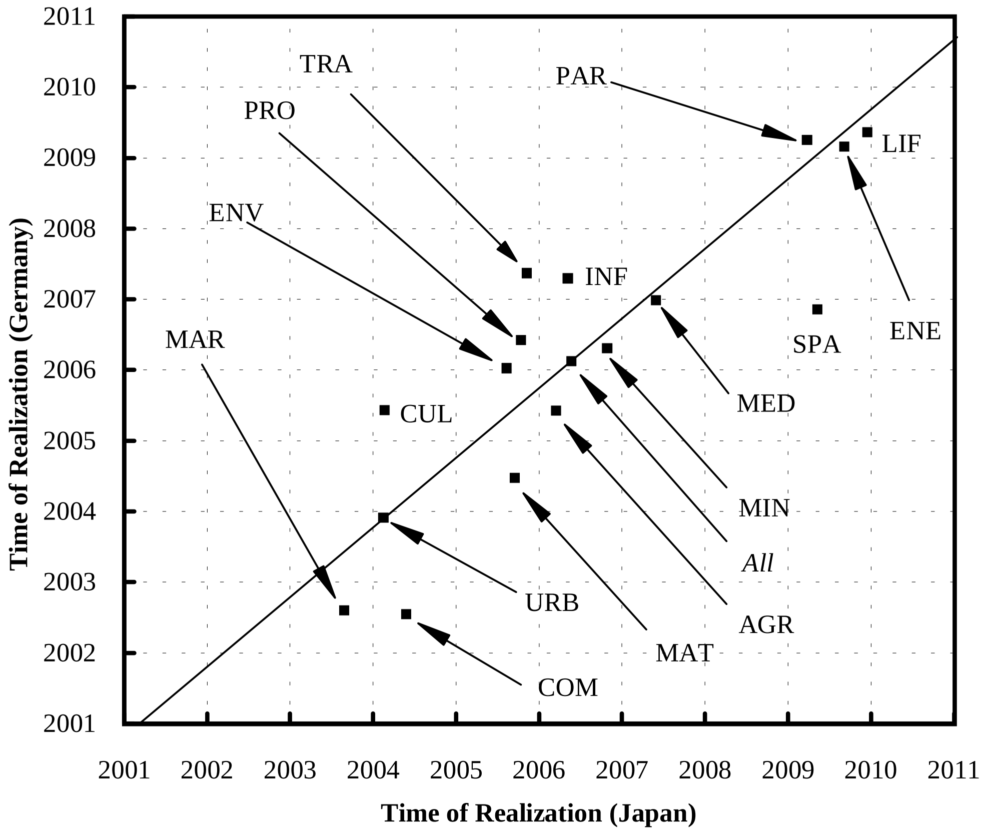
In Figure 2.3-2, Japanese and German forecasted realization times are plotted, and it can be seen that almost all topics are distributed in alignment with the straight line running through the origin (1990) and the average value for both countries. There

Figure 2.3-2: *Comparison of the Japanese and German forecasted year of realization of all topics (The drawn line connects the origin (1990) with the overall average value)*



were few topics in which there was a large difference in the forecasted realization time between Japan and Germany; 278 topics (24.3%) had a difference in forecasted realization time of less than one year, 506 topics (44.2%) had a difference of less than two years, and 709 topics (61.9%) had a difference of less than three years. Thus, it can be observed that in about two thirds of all topics, the difference is less than three years between Japanese and German forecasts.

Figure 2.3-3: Comparison of the Japanese and German forecasted year of realization per technological area (The drawn line connects the origin (1990) with the overall average value)



The technological areas with a forecasted realization time in the later years (average value later than 2009) in the Japanese survey are Life Sciences (lif), Energy (ene), Space (spa), and Particles (par) while the same areas apart from Space (spa) are also forecasted to be realized after 2009 in the German survey, so again, there is some conformity between the two surveys. Areas with a forecasted realization time in the earlier years (average value earlier than 2005) are Marine Science and Earth Science (mar), Communications (com), and Urbanization and Construction (urb) in both surveys.

Japanese and German trends generally conform in each technological area, and are almost all distributed in the vicinity of the straight line that connects the origin and the average of all topics (Figure 2.3-3). Areas with a considerable difference in which Japan's forecasted realization time is later than Germany's are Space (spa) and Communications (com), while those in which Germany's forecasted realization time is later are Transportation (tra) and Culture and Lifestyles (cul).

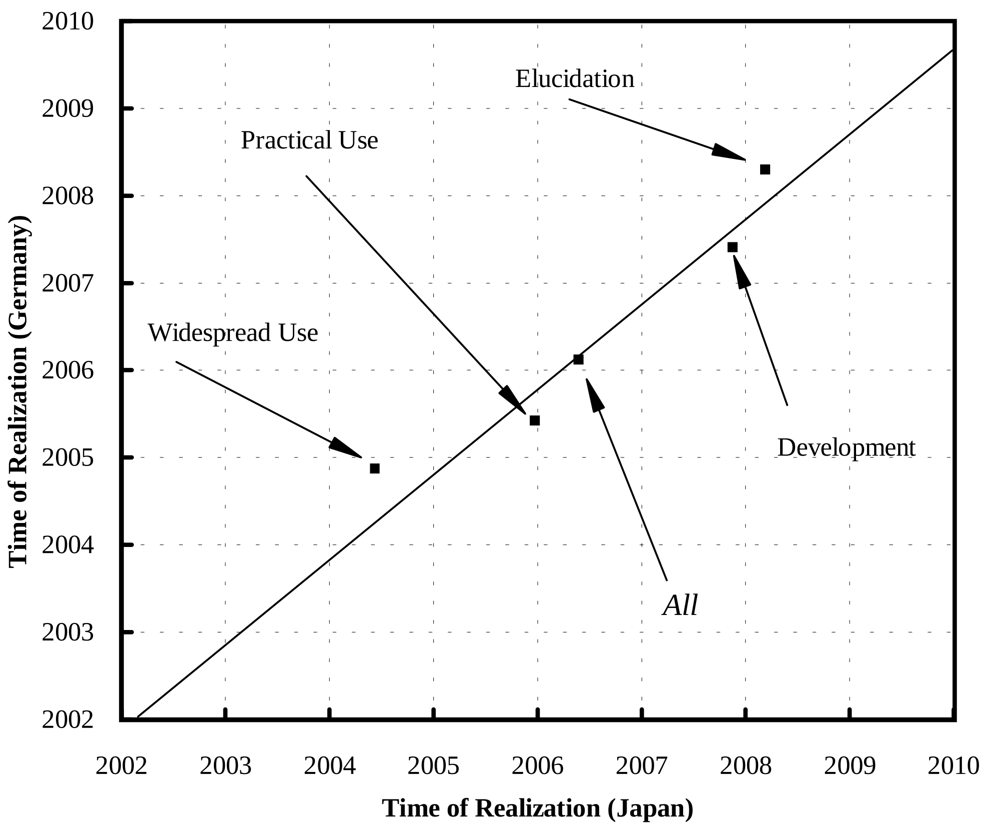
One area that is worth noting here in terms of the difference in the forecasted realization time is Communications (com) because both, the year 2004 forecasted in Japan and the year 2003 forecasted in Germany are relatively early, and a difference of almost two years (1.8 years, exactly) in relation to the time from the starting point of the forecast, 1991, (12-14 years) can be seen as quite significant. Geographical reasons may play a role, as the Widespread Use of communication infrastructure requires the development of remote areas in Japan which is more difficult than in central Europe. One factor behind the large difference in Space (spa) is thought to be structural as Japan carries out space development basically by herself whereas Germany participates in European space projects.

As for the three advanced technology areas of Life Sciences (lif), Information and Electronics (inf), and Materials and Processing (mat), there is conformity between the two surveys in Life Sciences (lif). The Japanese expectancy is earlier than the German in Information and Electronics (inf), and the German is earlier in Materials and Processing (mat). This is believed to be a reflection of the current state of research and development in the various areas of the two countries.

As for the three infrastructure areas of Urbanization and Construction (urb), Communications (com), and Transportation (tra), there is agreement between Japanese and German experts in Urbanization and Construction (urb). Germany is earlier in Communications (com) and Japan is earlier in Transportation (tra). An important element in these infrastructure areas is co-ordination with the social structure; for instance, the existence of not just the technological development itself but also a *social* infrastructure (e.g. crime prevention, health, education) which can accept the new technology and whether there is a social need for the new technology which might be a contributing factor to these results (see also chapter 4). The fact that an inverse phenomenon can be seen between the Japanese and German estimations in areas where the technology is relatively similar, such as Communications (com) and Information and Electronics (inf), demonstrates the influence of such infrastructure factors. Further explanations may be found in connection with the various constraints (chapter 2.7).

Figure 2.3-4 shows the average forecasted realization time for each stage. Both Japanese and German experts forecasted that the realization time will be progressively later through the technological stage order of Widespread Use, Practical Use, Development, and Elucidation. The average values for all stages are distributed close to the line connecting the origin and average of all topics, so in this respect, experts from both countries are in close agreement.

Figure 2.3-4: *Comparison of the Japanese and German forecasted year of realization by innovation phases (The drawn line connects the origin (1990) and overall average value)*



This finding proofs the general assumption that those innovations which are already in use will be widespread soon, and already developed innovations can be used relatively early. The last in this chronological order would be the topics on

Elucidation which will be realized very late in the future.

2.4 Foresight Precision

Any numerical result in technology foresight has to be characterised both in terms of accuracy and precision. *Accuracy* is a measure of how close the result of the experts' judgements comes to the "true" value. However, we do not know anything about the "true" future. The accuracy of forecasting methods can thus only be determined retrospectively (see Chapter 1.2). *Precision* is a measure of how exactly the result is determined without reference to any "true" value. If we determine the weight of this report at 13.578903 kg, this is certainly not an accurate result but it is very precise. The statement "about 1 kg" would be more accurate, but not very precise.

The precision of forecast data may be determined. A useful way of representing various degrees of precision is the calculation of quartile and median values and their graphical representation (for instance with respect to the time of realization as in the Japanese and German Delphi reports for each topic). The interpretation of "broad" and "narrow" distribution of estimates is, however, not straightforward. It may be the case that every expert comes up with similar forecasts resulting in high precision and narrow distribution of the collective estimation of the time of realization (it may turn out in the future to be "true" or not). But it may also be the case that there are two or more schools of thought among the experts who disagree on the timing of future events in disputed fields although they are certain that the precision to determine the realization is very high. In this case, we will observe a broad band of opinions although the precision of statements on the time determination is good.

In order to separate the real precision assessment from disagreement factors among experts, they were directly asked to answer the question whether the range of the forecasted realization time of each topic is a) less than five (Germany) or about three (Japan) years, (high), b) about five years (Japan: or less) (medium) or c) more than five years (low). As the given length of the intervals each covered a five year range, this means that the experts provided an answer to the tacit question that they a) could predetermine the time of realization more precisely than in the given five-year intervals, b) are quite confident with the given intervals and are certain which of the time intervals to tick, or c) even had difficulties to decide which of the given intervals to mark.

This chapter analyses the precision assessment which - for the reasons mentioned above - is free of biases towards the evaluation of the topic and is sometimes called *certainty* or *confidence* measure.

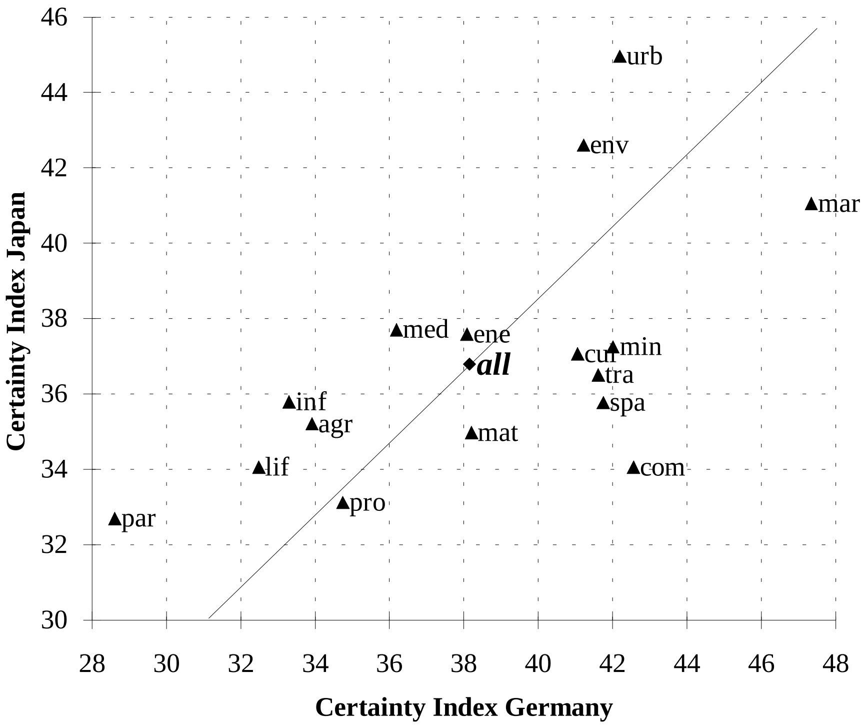
The overall estimation of the certainty index about the foreseen criteria is about 37 in Japan and about 38 in Germany which is, first, quite a similar estimation of precision in both countries. Secondly, it is definitely below 50, i.e. more experts think the precision per topic cannot be determined as precise as in five-year intervals. (An index of 50 can mean, for instance, that exactly the same number of experts answered with a) as with c) as defined above.) (Figure 2.4-1).

Regarding both countries, the certainty is highest in Marine Sciences and Earth Sciences (mar), Environment (env) and Urbanization and Construction (urb) and lowest in Production (pro), Life Sciences (lif) and Particles (par). The last two areas mentioned are scientific fields comprising many problems which require a breakthrough solution so that a judgement on certain topics cannot be expected to be precise. It is unclear why the Production field (pro), with many practical topics, is so difficult to forecast.

There are some differences concerning certain technological areas. In Communications (com) and in Marine Science and Earth Science (mar), the German experts' confidence in their estimation is much higher (more than 6 index points) than that of their Japanese colleagues.

In Space (spa), Transportation (tra), Mineral and Water Resources (min) and Culture and Lifestyles (cul), there is a difference in the index of about 4 to 6 points between the Japanese and German estimation. In all other cases, the difference in the degree of precision is less than 4 and thus, negligible. Whereas in two of these technological fields, this result could have been expected because the know-how on the space and transportation techniques is widespread in Germany as well as in

Figure 2.4-1: Comparison of the Japanese and German experts' certainty per *technological areas (The drawn line passes through the origin and the overall average value)*



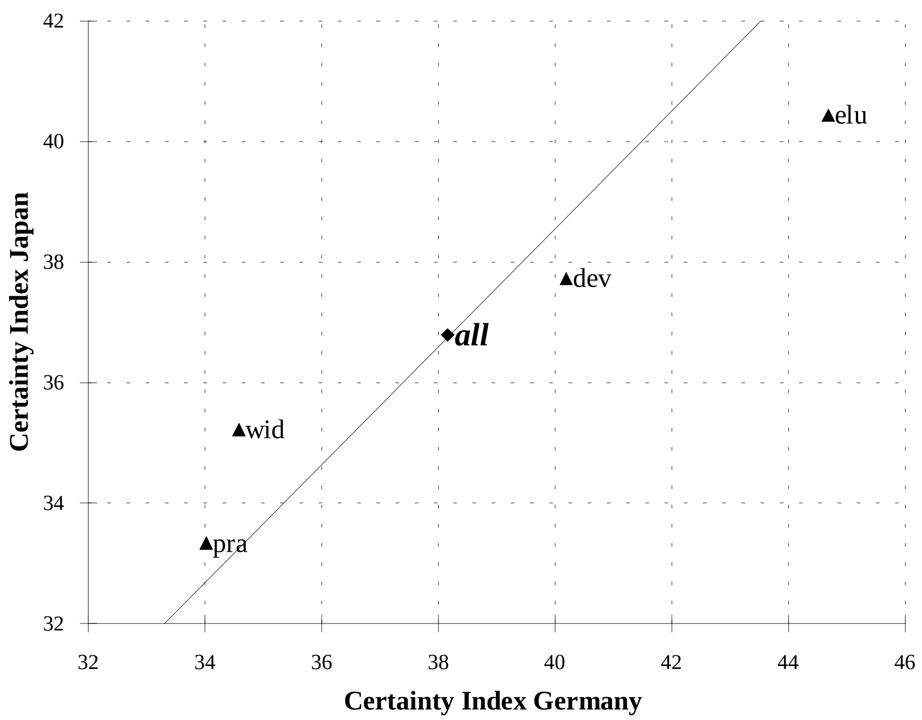
Japan, the German science communities are educated to demonstrate more self-confidence than probably Japanese people both in space (European joint programmes) and in terrestrial transportation (large car industry, only European country with no speed limit on highways).

The results in Marine Science and Earth Science (mar) and Culture and Lifestyles (cul) are not easily understood. Both fields contain topics which are not typically German, e.g. volcanoes, earthquakes or the typical Japanese education system and education targets. The expert knowledge in these fields is quite similar (see Figure 2.1-1) so that it cannot be explained by having asked higher-ranking experts to participate in the survey who - of course - would estimate their precision higher than the experts who categorise themselves in "lower expertise". Why the certainty of German experts in the field of Communications is higher than the Japanese also has to be clarified by further investigation.

Looking at the technology development phases, topics on Practical (pra) and

Widespread Use (wid) of innovations are evaluated with the lowest degree of certainty in both countries. The difference in the estimation of these phases is negligible (about 1 index point). The difference in the overall assessment is similarly negligible (about 1 index point higher in the German survey; see also figure 2.4-1).

Figure 2.4-2: *Comparison of the Japanese and German experts' certainty assessment by innovation phases (The drawn line passes through the origin and the overall average value)*



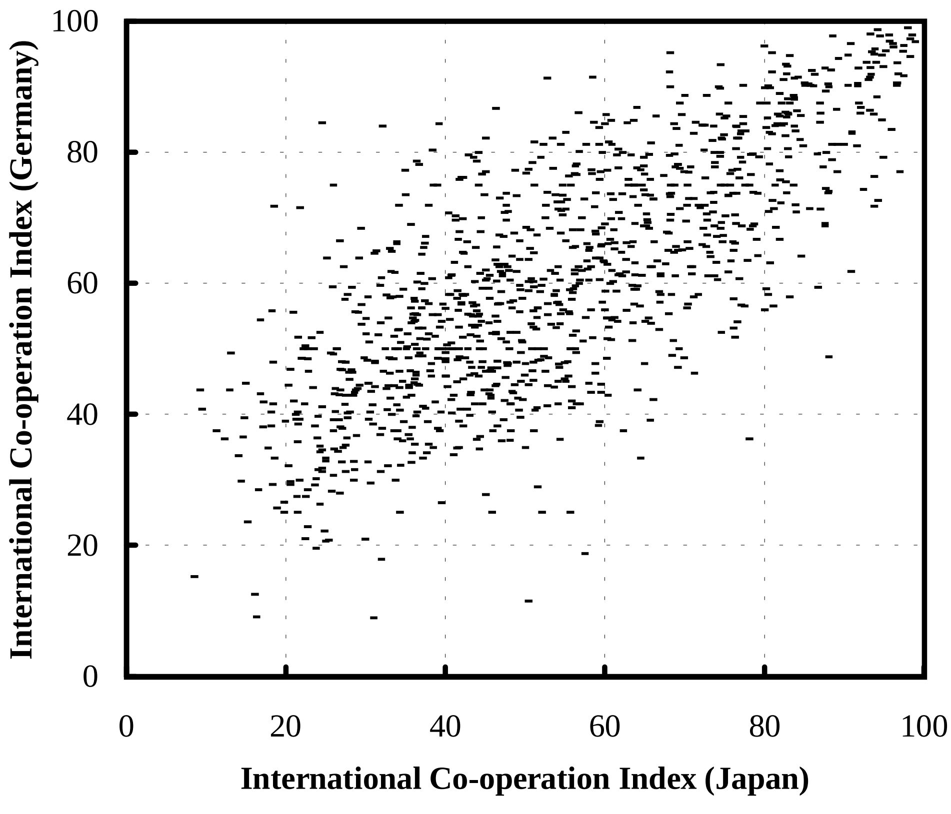
The difference in Development (dev) is slightly higher (index about 2) and the largest discrepancy can be noticed for Elucidation (elu, more than 4 index points) which are also the topics with the highest precision in both countries.

This is somewhat surprising as it is generally assumed that topics concerning the elucidation of a phenomenon and the development of a prototype cannot be predicted with high confidence whereas it would be easier to forecast innovations for Practical and Widespread Use. The reason may be found in the specific character of the topics chosen for the Delphi survey, but has to be found out by further investigations. It has to be born in mind that largely technical experts answered the questions. They may be more certain about experimental development and scientific clarification than about the non-technical constraints that hinder or retard Practical and Widespread Use.

2.5 International Co-operation

The average for necessity of international joint development for all topics is 54 in the Japanese survey and 61 in the German survey, indicating that German experts place greater emphasis on international co-operation. The difference might result from the geographical environment of Germany, which is situated adjacent to other industrialised countries, in contrast to Japan, which is an island nation (for details see chapter 4.4).

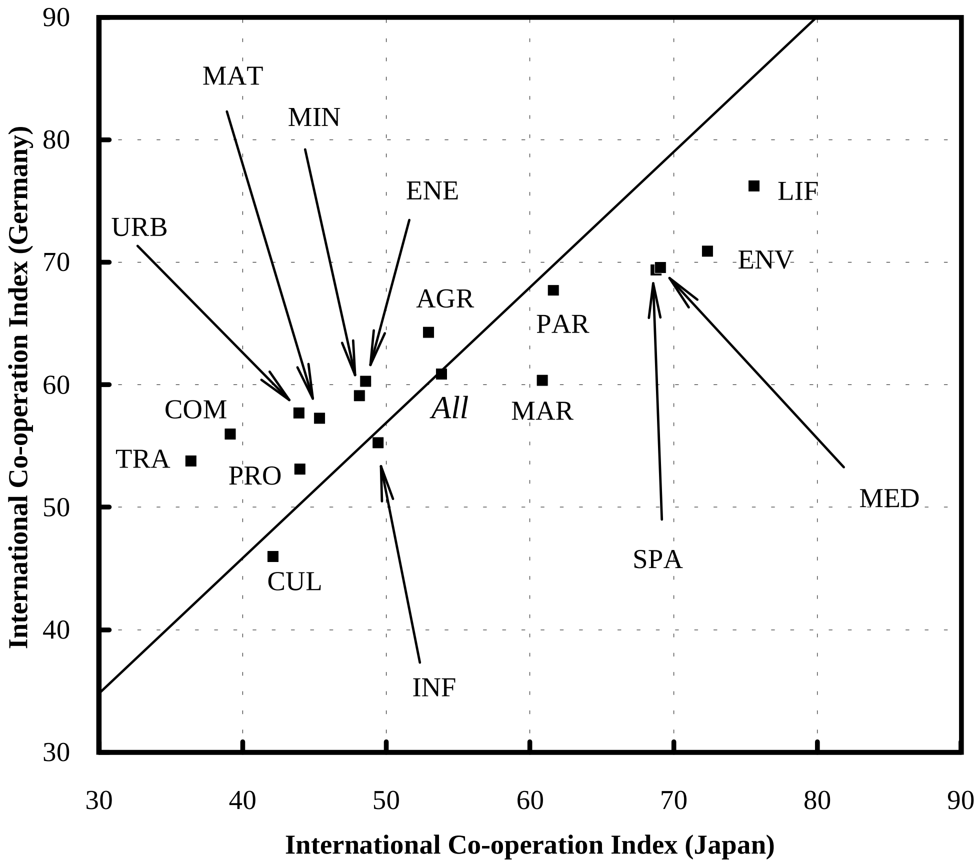
Figure 2.5-1: Comparison of the Japanese and German necessity for international co-operation of all topics



Many of the topics with the largest difference between Japan and Germany in the necessity of international joint development naturally require co-operation with neighbouring countries because they are related to marine and water systems and controls which are often shared between European countries (The Channel, the Baltic Sea, border rivers etc.).

In contrast, there are some topics in which the necessity of international joint co-operation was considered to be higher for Japan than for Germany (details in chapter 4.4). These topics lean towards Earth Science which is also an indication of the influence of the geographical environment. Although differences do exist for

Figure 2.5-2: *Comparison of the Japanese and German necessity for international co-operation per technological area (The drawn line passes through the origin and overall average value)*



individual topics, overall, the awareness of Japanese and German experts regarding the necessity of international joint co-operation in R&D in the various topics tends to be similar (Figure 2.5-1).
Figure 2.5-2 compares the Japanese and German averages for necessity of international joint development in each technological area.

In both countries, the necessity of international co-operation is considered to be high in Life Sciences, Environment, Medical Care and Health, and Space. In these four areas Japan places the same emphasis on international co-operation as Germany does, but all lie to the right and below the solid line that joins the origin and the overall average at Figure 2.5-2.

This means that in both countries, uniformly, these areas are considered as subjects of above-average co-operation which in relative terms is more pronounced for Japan with an overall lower co-operation rate.

In general, there tends to be overall conformity between Japan and Germany in the ranking of necessity on international joint development and this conforms with the analysis of the topics mentioned in the overall trend section (i.e., for Germans co-operation is generally more important). The areas, in which Germany places even greater importance on international co-operation (above average) are the infrastructure areas of Transportation, Communications, and Urbanization and Construction. Of the three areas of advanced technology, Germany places greater importance on Materials and Processing while for Life Sciences, the countries judge equally, which places Japan on an above-average position. Overall there was no particular bias observed in the three areas.

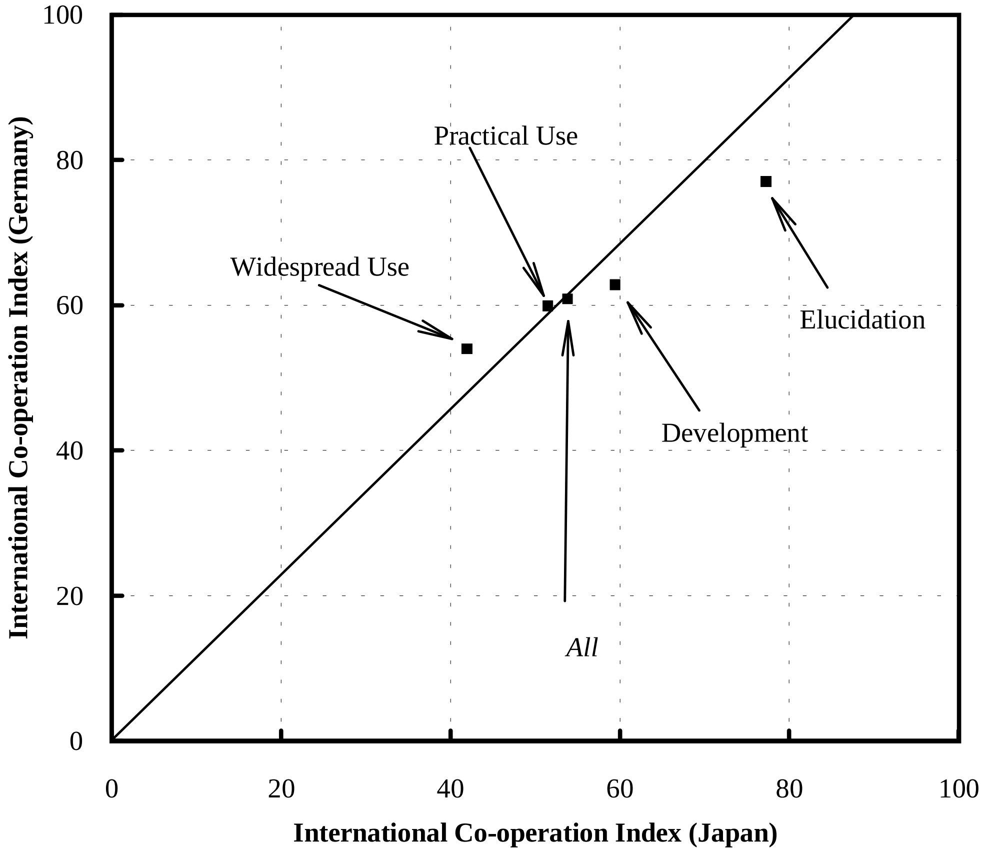
The averages for necessity of international joint development by stage is shown in Figure 2.5-3. In both the Japanese and German surveys, the necessity of international co-operation is considered highest in the Elucidation stage, and as the application progresses through Development, Practical Use, and Widespread Use, the necessity of international co-operation tends to decrease. However, the rate of lowering in the perceived necessity of international joint development following a shift in stages is lower for Germany. The necessity of international co-operation in topics in the Widespread Use stage is also considerably higher in Germany than in Japan. The reason for this is thought to be that Germany is a continental nation so there is a considerable need for joint technological development with neighbouring countries in the Widespread Use stage topics, whereas Japan is an island nation

where is less need for joint technological development with other countries in the Widespread Use stage topics.

The reason for the necessity of international co-operation in the Elucidation stage topics being especially high in both the Japanese and in German surveys is that topics in the Life Sciences and Environment areas, where there is a very high need for international co-operation, account for 61%

of the Elucidation stage topics.

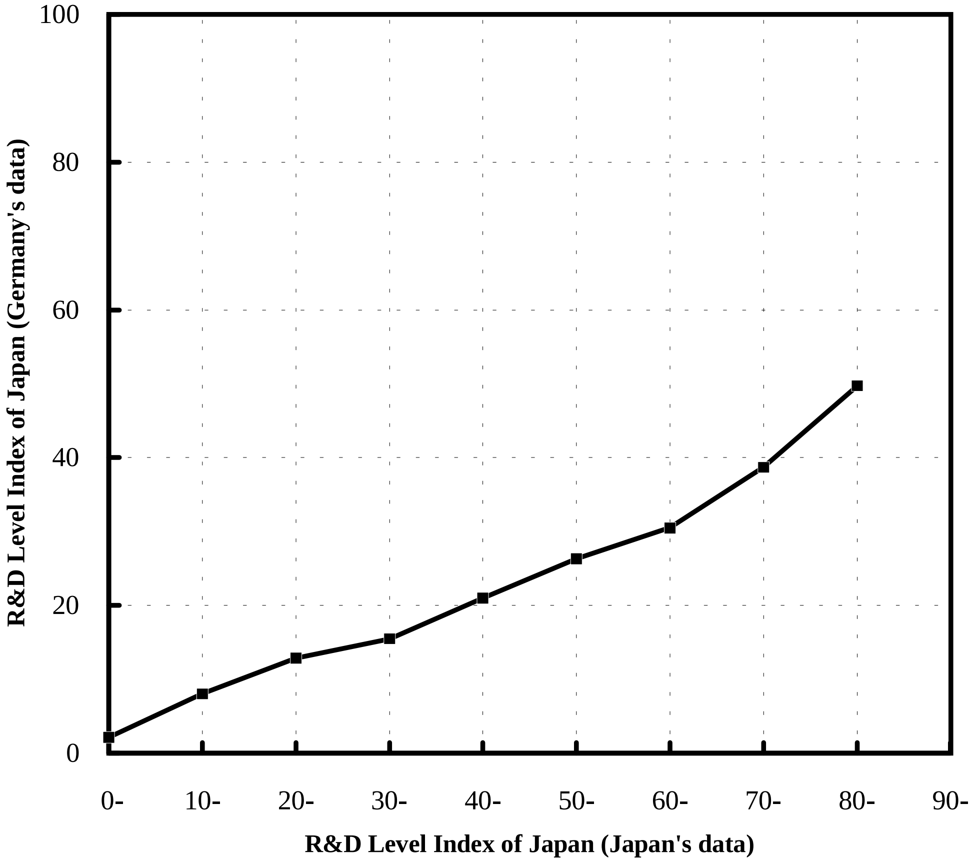
Figure 2.5-3: *Comparison of the Japanese and German necessity for international co-operation by innovation phases (The drawn line passes through the origin and overall average value)*



2.6 R&D Level

In the second round of the Japanese and German Delphi survey, it was asked for the *international comparison of the level of research and development* or (in the

Figure 2.6-1: *Relation of the R&D level of Japan between Japan and Germany ("R&D level 90-" are omitted in this figure because of the number of corresponding topics is only four)*



Japanese survey) *the comparison of the current R&D level between Japan and other countries* regarding the specific topic. As this criteria was only asked for in the second round, the respondents were not provided with the estimation of their colleagues from the first round. Thus, this category does not claim to represent a consensus as in the other divisions.

Since the R&D level was asked for with different categories in the two surveys, it is impossible to make any direct numerical comparisons between the two countries in this field (see chapter 1.5.6). It is, however, possible to compare the trends in the rating of Japan's R&D level by Japanese experts and also by German experts. As can be seen in Figure 2.6-1, topics that are rated highly in respect of Japan's R&D level by Japanese experts are also rated highly by German experts. So while it is impossible to compare results for the R&D level in terms of absolute numerical values, analysis of the trends is possible and significant.

2.6.1 The Japanese View

The 1,146 topics were classified into the following groups of topics based on the comparative index value of Japan's R&D level.

"Japan is more advanced" (index: 70-100)
"Japan is slightly more advanced" (index: 55-70)
"Equivalent" (index: 45-55)
"Other countries are slightly more advanced" (index: 30-45)
"Other countries are more advanced" (index: 0-30)

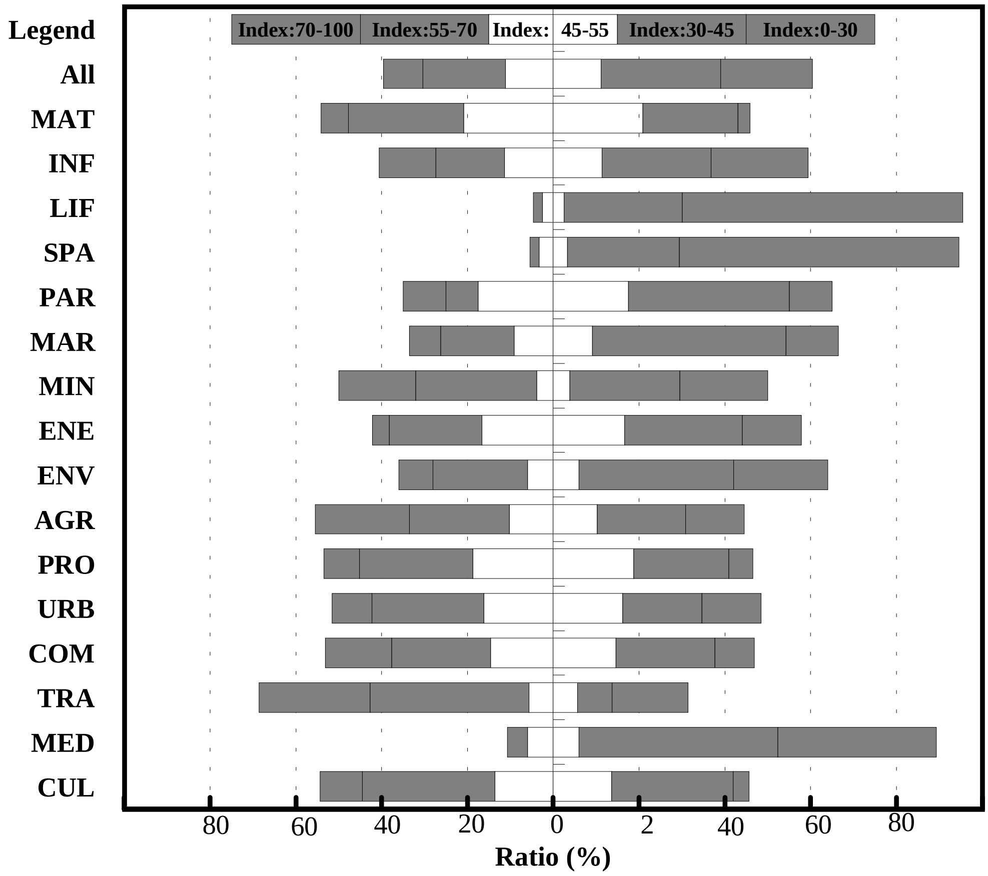
Figure 2.6-2 shows the R&D level for each technological area based on this classification.

On the whole, Japanese experts assess the R&D level overseas higher than that in Japan. The result of classifying all topics into the five groups is: "Japan is more advanced" - 9.1%; "Japan is slightly more advanced" - 19.5%; "equivalent" - 22.3%; "other countries are slightly more advanced" - 21.8%, and "other countries are more advanced" - 21.5%.

The three areas in which Japanese experts assess Japan's R&D level as far behind other countries are Space, Life Sciences, and Medical Care and Health, followed by Marine Science and Earth Science, Particles, and Environment. Japanese experts rate Japan's R&D level higher than that overseas in Transportation, Agriculture,

Figure 2.6-2: Trends in each technological area comparing the current R&D level of

Japan and other countries (Japanese survey) (Note on the classifications: "Japan is more advanced": index 70-100; "Japan is slightly more advanced": index 55-70; "Equivalent": 45-55); Other countries are slightly more advanced": index 30-45; "Other countries are more advanced": index 0-30)



Forestry and Fisheries, and Communications. Japan's R&D level is assessed as equivalent to that overseas in Information and Electronics, and this is clearly contrary to the general perception that Japan's electronics industry is a world leader.

Explanations for this are, first, the predominance of the United States and other countries in the two domains of software and bioelectronics within this area. These two technological domains account for, respectively, 27 and 13 of the 106 topics in the Information and Electronics area, and the indices for "Japan is more advanced" in the two domains are both quite a low 37. Conversely, the corresponding indices in microelectronics (21 topics) and optoelectronics (18 topics) are much higher at 55 in both cases, indicating that Japan is more advanced in these two technological domains.

Second, Japanese experts think that Japan will not be able to maintain its current predominance in long-term technological development. This can be taken as a sign of a sense of crisis that Japanese experts feel about basic research, which forms the basis of future technological development and growth.

Figure 2.6-3: R&D level by innovation phases (Japan)

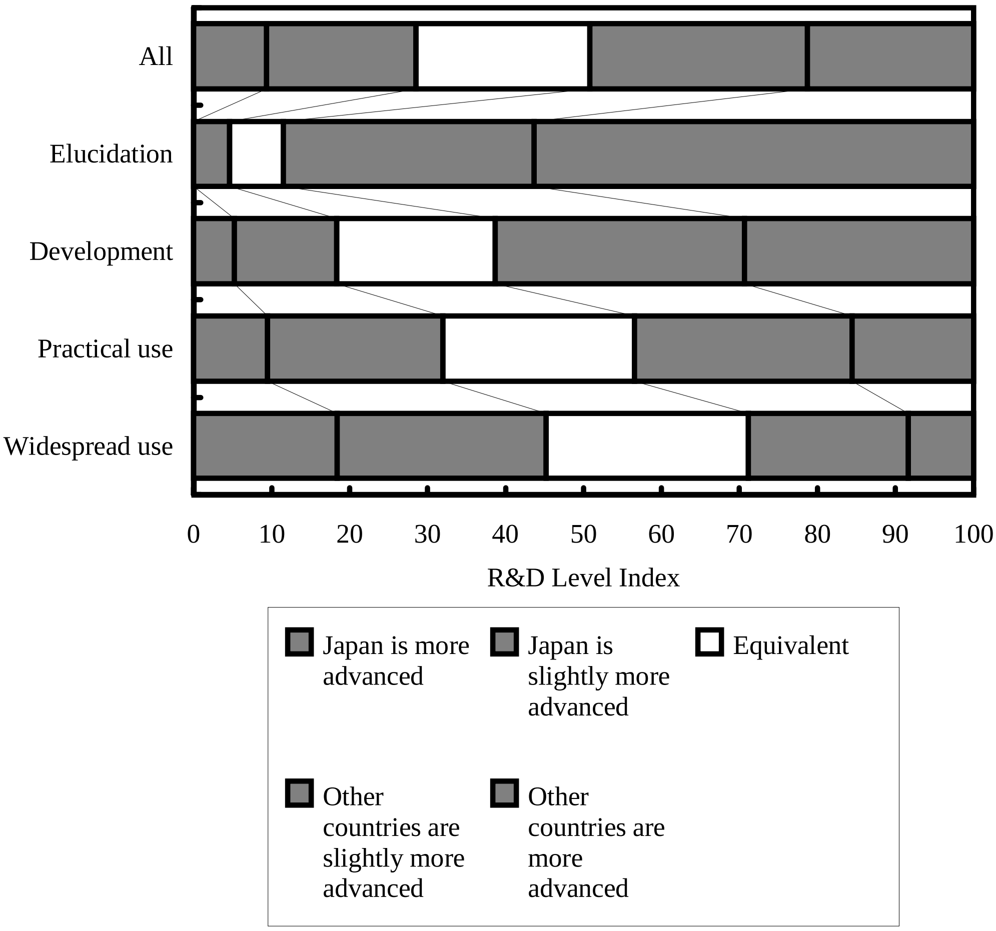
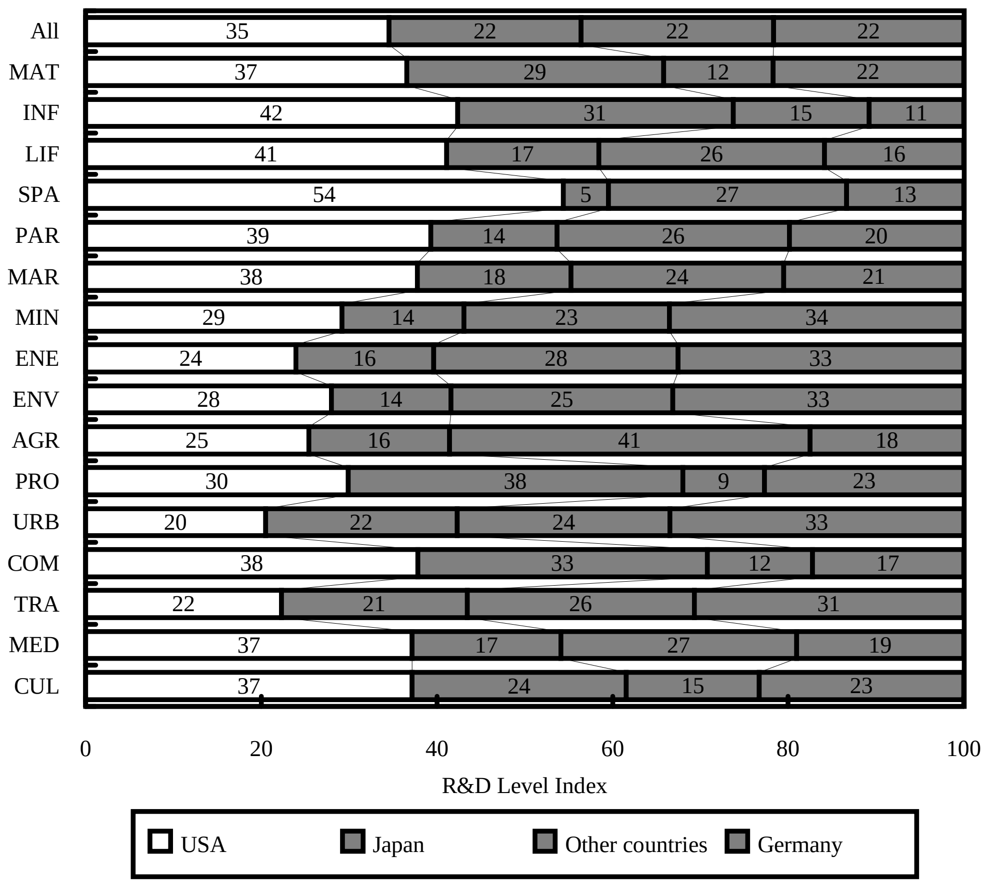


Figure 2.6-3 shows the results for the five classifications mentioned above for each technological stage. Japanese experts believe that Japan's R&D level is lowest in the Elucidation stage, after which the R&D level rises through successive stages. Japan's R&D level was equivalent to or higher than that overseas in 71.1% of the topics in the Widespread Use stage, whereas the corresponding percentage for topics in the Elucidation was no more than 11.5%. The results of this assessment of R&D levels shows that there is a strong need for Japan to enhance basic research.

2.6.2 The German View

Figure 2.6-4 shows German experts' assessments about R&D levels. Percentages for

Figure 2.6-4: Trends in each technological area comparing the current R&D level (German survey)



"USA", "Japan", "other countries", and "Germany" show the extent to which each country or country group is estimated to be a world leader in the various technological areas.

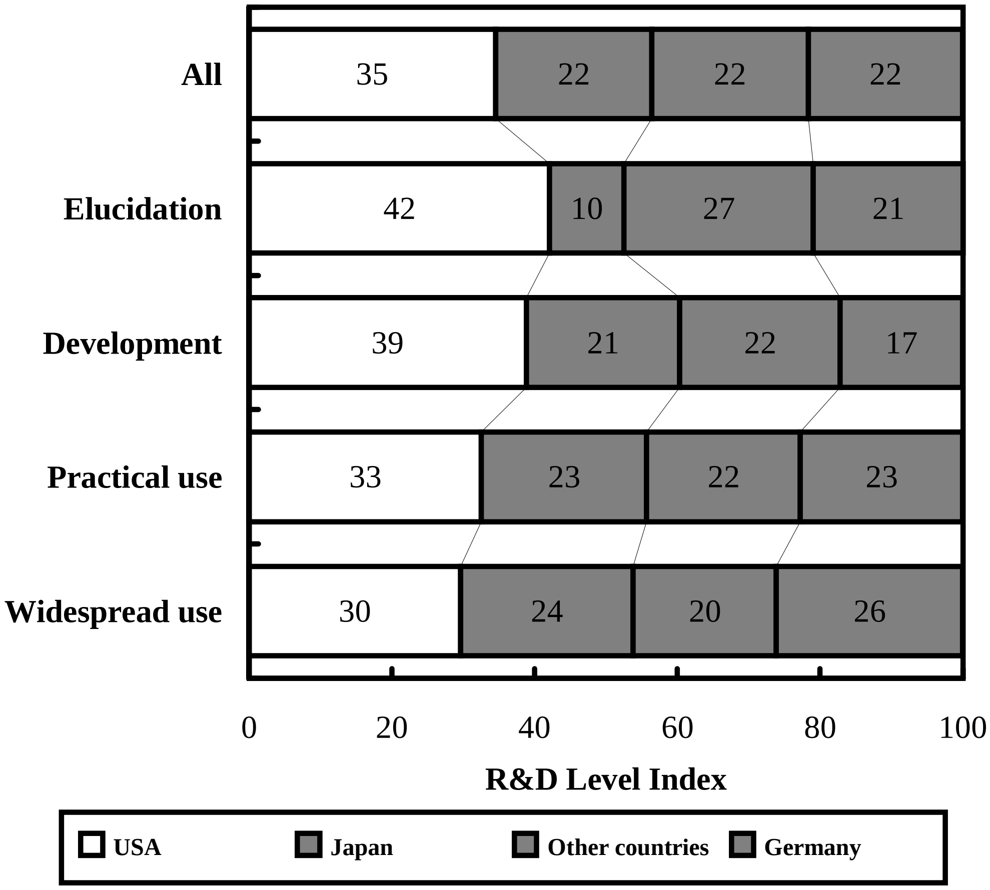
Overall, the R&D level of the United States is far above all others, while the R&D levels of Japan, Germany and other countries are judged to be roughly the same. Areas in which Germany is assessed as having a high level of R&D are Mineral and Water Resources, Urbanization and Construction, Environment, Energy, and Transportation. In these five areas, Germany's R&D level is assumed to be the most advanced in the world. In contrast, areas in which Germany's R&D level is assessed as low are Information and Electronics, as the lowest, followed by Space, Life Sciences, and Communications.

The United States has an R&D level far in excess of all others in the three advanced technological areas of Life Sciences, Information and Electronics, and Materials and Processing, as well as showing an overwhelming capability in Space. The United States hold the top position in nine of the sixteen technological areas, and are rated highly in the areas of advanced technology and the areas that lean heavily towards basic technology or basic research.

Japan is assumed to be more advanced than the United States in Production, and is also rated quite highly in Communications, Information and Electronics, and Materials and Processing. Comparing this with the assessment made by the Japanese experts in 2.6.1, we can see that Japan's R&D level is rated higher by German than by Japanese experts in Life Sciences, Production, and Information and Electronics, while it was estimated by the Japanese experts to be higher in areas that are considered to be greatly affected by the geographical environment, namely Agriculture, Forestry and Fishery, Mineral and Water Resources, and Transportation.

In Figure 2.6-5, the R&D level in the various countries for each technological stage is compared. Germany's R&D level seems to be lowest in Development, and rises through successive stages of Elucidation, Practical Use, and Widespread Use. The United States' R&D level is, according to the German estimation, extremely high in Elucidation, then lower in the successive stages of Development, Practical Use, and Widespread Use. But in all stages, it holds the top position. Japan's R&D level in the Elucidation stage is assumed to be quite low compared to Germany's, while it is assessed as slightly higher than Germany's in Development, and about the same in the Practical Use and Widespread Use phases.

Figure 2.6-5: R&D level by innovation phases (Germany)



The assessment of Japan's R&D level by German experts for each of the stages is roughly the same as that made by Japanese experts as shown in Figure 2.6-3, and further substantiates the notion that Japan has to put more effort into basic research.

2.7 Constraints

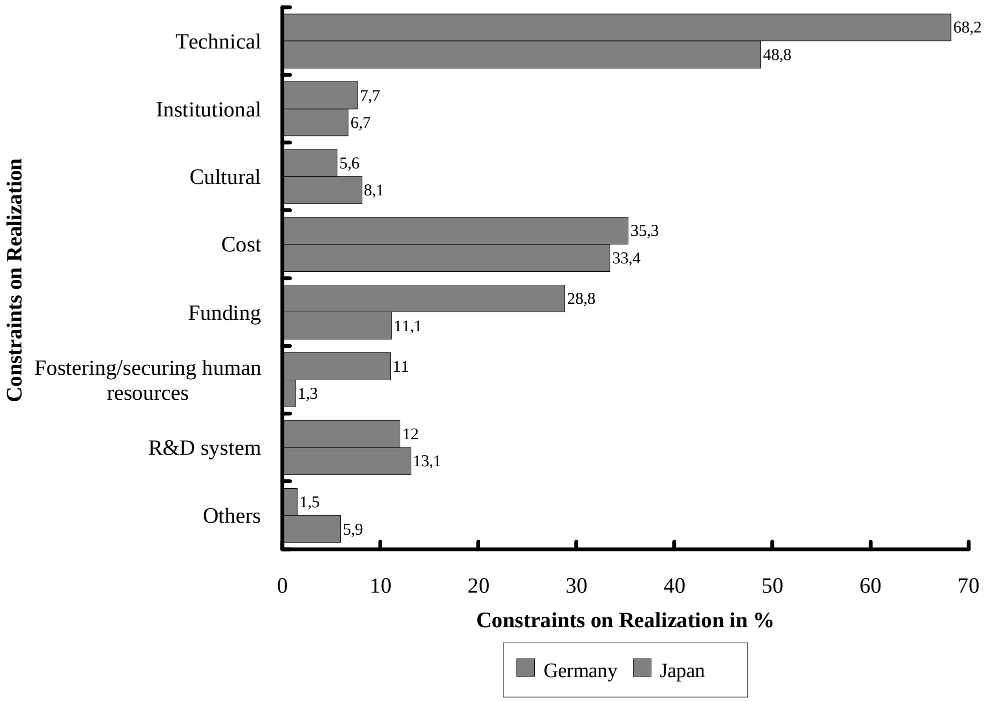
The Delphi surveys both asked for an estimation, which kind of constraints will hamper the realization of the topic asked. The responding experts could choose between technical, institutional, cultural and cost constraints as well as funding, fostering or securing the necessary human resources, the R&D systems and others, which they could specify in the comments.

As for constraints which make the realization of the topics more difficult (for calculation see chapter 1.5), experts from both countries naturally point out that the main constraint lies in the difficulties of the technology itself. Next is the cost factor, and it is pointed out that high costs of developing a new technology and replacing existing technology with the new one is a major problem.

Two constraints in which there is a considerable divergence of opinions between Japanese and German experts are *funding* and *fostering or securing human resources*. The average value for funding constraints is 29 per cent for Japan, and this is almost three times the value recorded for Germany (11 per cent). As for constraints in securing human resources, Japan's average evaluation of 11 per cent contrasts with the 1 per cent for Germany, where the human resources are considered to be only a very minor problem if at all. Whereas Japanese experts indicated funding as the next major constraint after costs, German experts pointed to constraints in the R&D system (Figure 2.7-1).

A wide gap can be seen between the two countries in the aspect of *funding* constraints. One factor contributing to this gap is thought to be subtle differences in the translation of the question. In the German question, the word "Kapitalmangel" (shortage of capital) was used, and nuance-wise, the question was understood as "is there a problem in the size of capital?". ISI was aware of the potential problem when the question was translated into German, but there was no other suitable German expression. This might be the reason why few German experts pointed out funding as a key constraint.

Figure 2.7-1: Japanese - German comparison of constraints on realization



But by many German experts, this constraints was understood in the same way as in Japan, and several of them commented on the fact that generally there is *no* shortage of capital but the capital is for other reasons not in fact invested in this kind of research. Therefore, they did not tick "shortage of capital" but rather "R&D system", "Costs", or "Others" for political reasons, or e.g. indecision. A robust interpretation of the funding constraint cannot be clarified by the existing Delphi data from both countries but needs further investigation about the respective funding systems.

The current state of R&D spending in Japan and Germany is therefore thought to have had some influence on this gap in the indication of funding by the two groups of experts. The German government's share of the gross national R&D spending is 37.2% (1991), while the Japanese government's share is 18.5% (1991), or only about half of the German government's share (in absolute terms it is about the same amount of money for the smaller and the larger of the two countries), and this is thought to have strengthened Japanese researcher's estimation about a shortage of funding, especially in the basic research area. Another aspect which is thought to have further widened the gap between Japanese and German researchers in the indication of funding constraints is the amount of research spent per researcher; Japan spends 0.106 million current PPP $ per researcher (1989), while Germany's spending is 1.6 times as high as 0.172 million current PPP $ per researcher (1989) (Appendix 1).

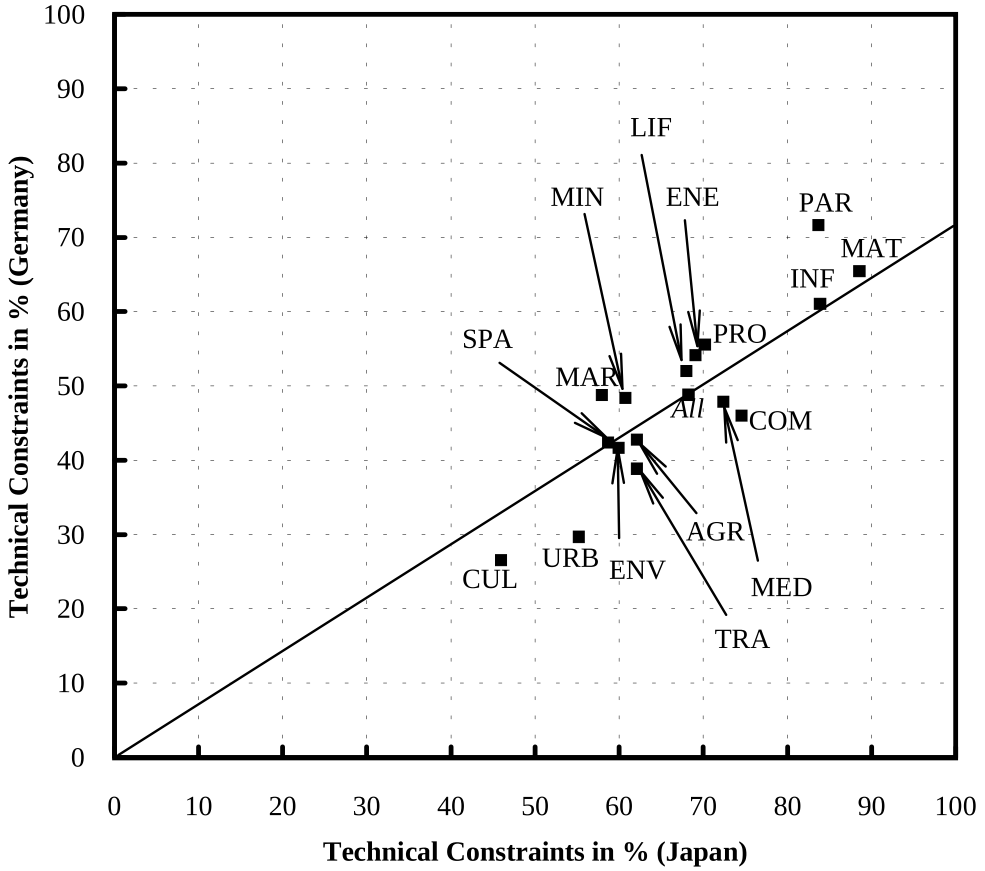
The low indication by German experts of constraints in fostering or securing of human resources can be attributed to special circumstances, in that the number of researchers in Germany rose sharply with the addition of scientists and engineers from the former East Germany following the unification.

2.7.1 Technical Constraints

Japan's average estimation for technological constraints for all topics is 68 per cent, much higher than German's corresponding average of 49 per cent. However, in almost all technological areas, the average is generally distributed along the line connecting the origin and the overall average, so relatively speaking there is a close conformity between Japanese and German experts in the various areas ranking by technical constraints. A high percentage of both Japanese and German experts point to technical constraints as a major problem in Particles, Materials and Processing, and Information and Electronics, while a low estimation can be seen in Urbanization and Construction, with Japanese experts indicating technical constraints in this area 1.8 times as often as German experts, and Culture and Lifestyles with a 1.6 times higher assessment.

The assessments of Japanese and German experts are split in the three advanced technology areas of Materials and Processing, Information and Electronics, and Life Sciences, and the three infrastructure areas of Urbanization and Construction, Communications, and Transportation with technical constraints being pointed out slightly higher by the German experts than by the Japanese experts on the three advanced technology areas, and higher by the Japanese experts than by the German experts in the three infrastructure areas (Figure 2.7-2).

Figure 2.7-2: Comparison of the Japanese and German technical constraints per *technological area (The drawn line passes through the origin and the overall average value)*

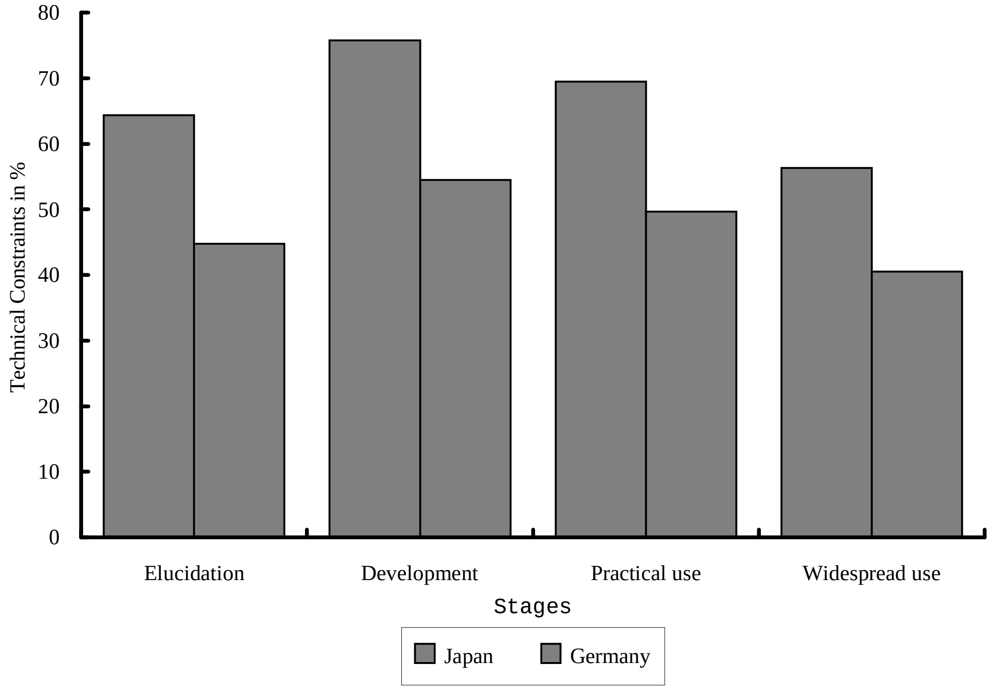


As for the technological stages of the various topics, although Japanese experts indicated technical constraints more than their German counterparts in all stages, the relative rankings of each stage are exactly the same for both groups of experts. Moreover, technical constraints were pointed out to be the most by both Japanese and German experts in the Development stage (Figure 2.7-3).

The more a topic approaches Practical or Widespread Use, the less frequent technical constraints are brought forward by the experts. On the other hand, scientific clarifications are often so basic in nature, that problems of *technical* realization cannot be thought of, yet. Therefore, the imagination of technical constraints is difficult in topics where scientific breakthroughs have not yet come.

The central focus of this chapter, unfortunately cannot be further illuminated by the data alone: the reasons why the German science and technology community plays down technical problems in innovation projects remains unclear.

Figure 2.7-3: Comparison of the Japanese and German technical constraints by innovation phases

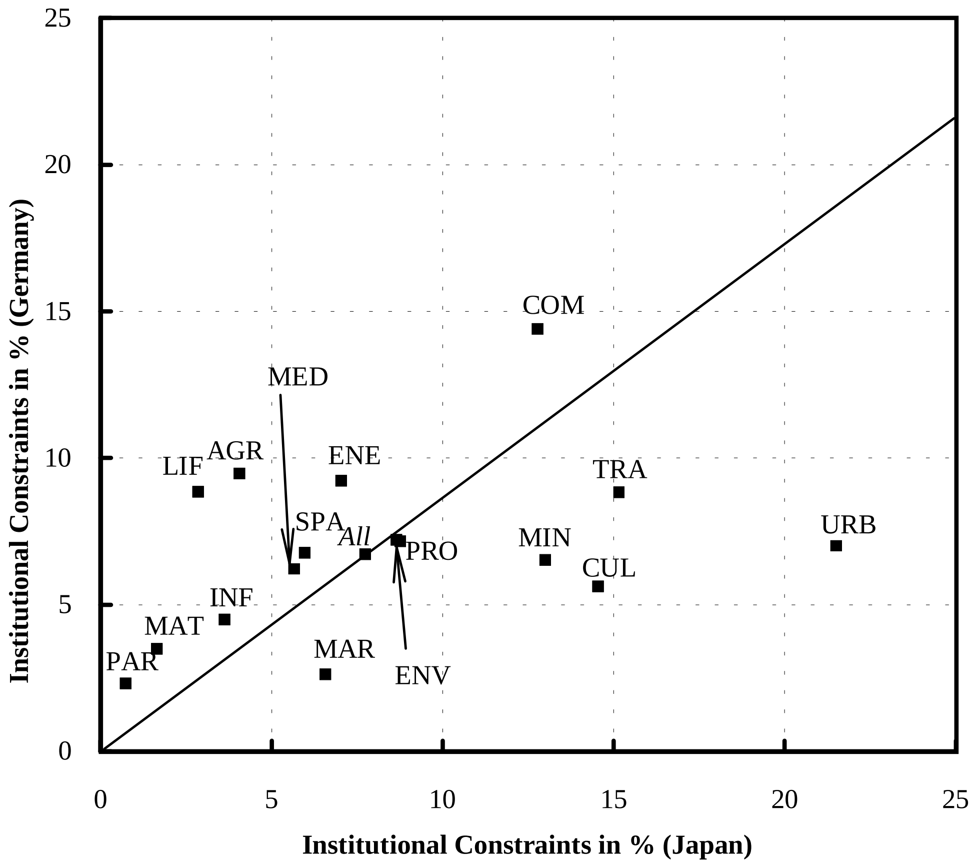


2.7.2 Institutional Constraints

Considering all topics, there is not a great difference between the evaluation of Japanese and German experts in institutional constraints; the Japanese average for all topics is 8 per cent compared to Germany's average of 7 per cent. In the Japanese survey, the estimation for institutional constraints is high (ten or above) in Urbanization and Construction, Transportation, Culture and Lifestyles, Mineral and Water Resources, and Communications, while in the German survey, Communications is the only area where the evaluation is above ten per cent. Comparing the results we can see that the Japanese percentage is higher in Urbanization and Construction, Culture and Lifestyles, Transportation, Mineral and

Water Resources as well as Marine Science and Earth Science, while the German percentage is higher in Life Sciences, and Agriculture, Forestry and Fisheries. The fact that there is a considerable difference between Japan and Germany in the evaluation for institutional constraints can be seen as a product of the different set of circumstances in the two countries as mentioned above.

Figure 2.7-4: *Comparison of the Japanese and German institutional constraints per technological area (The drawn line passes through the origin and the overall average value)*



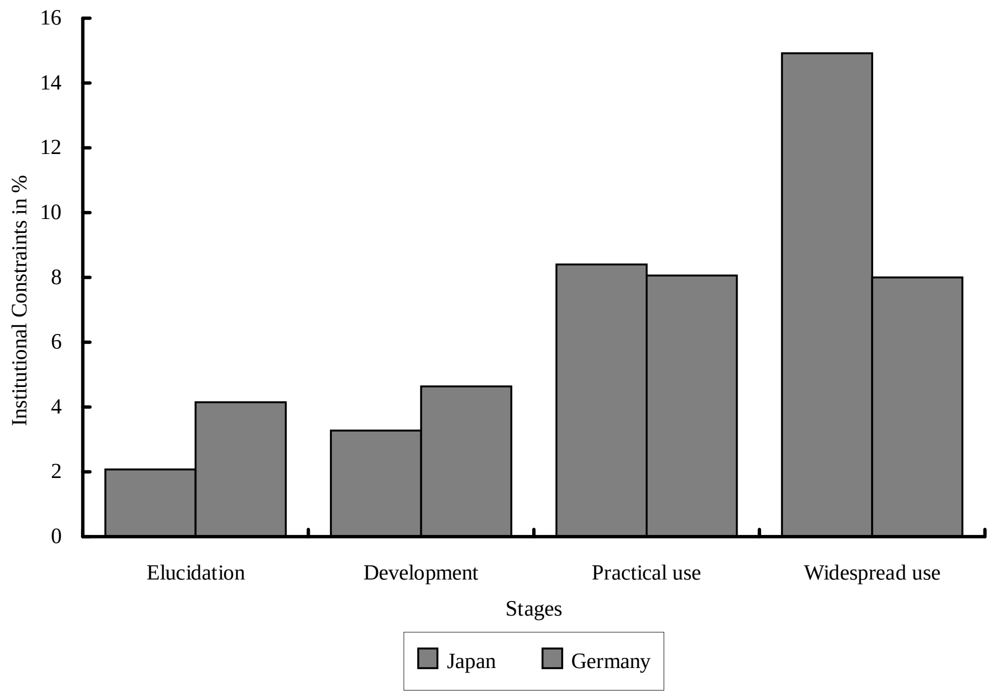
There is quite a difference between the three advanced technology areas and the three infrastructure areas, with the Japanese experts pointing to institutional constraints in the three infrastructure areas to a much greater extent than in the three advanced technology areas. The Japanese estimation for

Urbanization and Construction is three times as high as the German. As for comparison of assessments by the two groups of experts, in all three areas of advanced technology, the German experts pointed to institutional constraints more often than Japanese experts; the German percentage for Life Sciences is three times as high as the Japanese one. Of the three infrastructure areas, Japan's assessment of institutional constraints is relatively high in Urbanization and Construction and Transportation (Figure 2.7-4). It is not surprising that innovation in fields where the physical infrastructure matters are more affected by country-specific constraints, like laws, standards, norms, and guidelines which sum up to distinct institutional frame conditions and settings in Japan and central Europe.

Regarding the technological stages, we can see that the trends for Japan and Germany are similar in that the evaluation increases in the successive phases from Elucidation to Widespread Use, though German experts rated institutional constraints roughly similarly in Widespread Use and Practical Use, while the extremely high rating in Widespread Use by the Japanese experts is outstanding (Figure 2.7-5).

This means that often legislative institutions are a major hindrance to the application and Widespread Use of Urbanization and Construction technology in the Japanese society which has a particularly high level of institutional constraints imposed upon it, and other forms of technology that have reached the Practical Use stage, and suggests that deregulation is from the viewpoint of promising the development and utilization of long-term technology especially necessary.

Figure 2.7-5: *Comparison of the Japanese and German institutional constraints by innovation phases*



2.7.3 Cultural Constraints

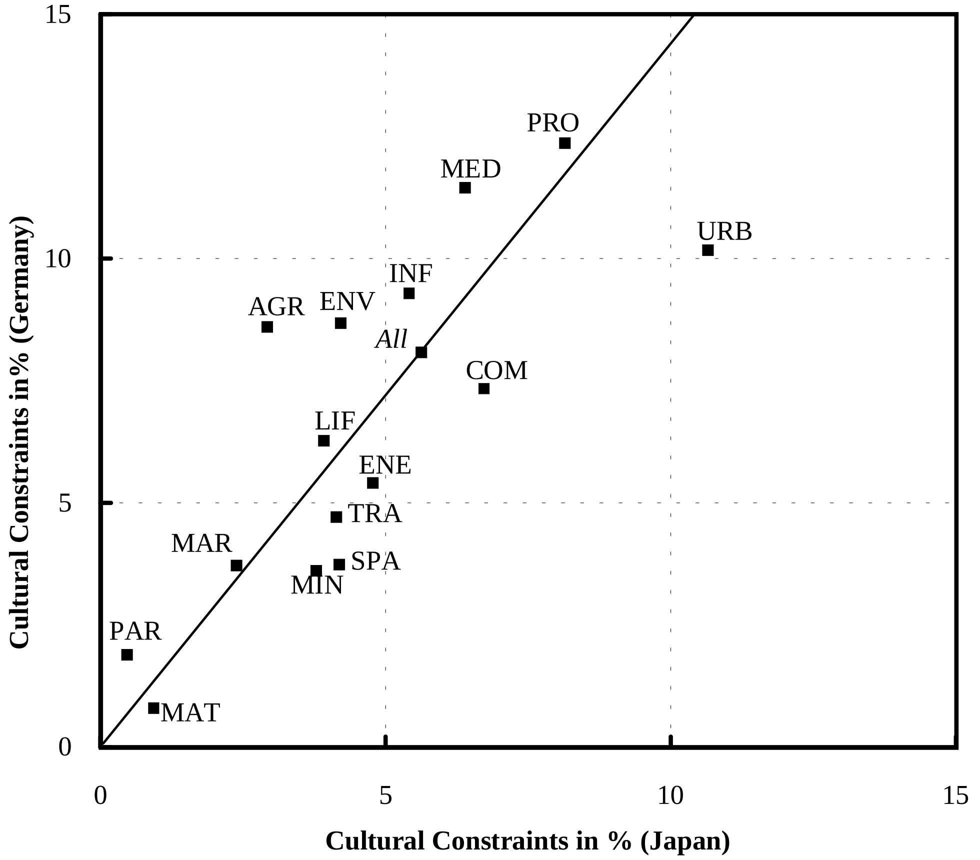
The German average in cultural constraints for all topics is, at 8 per cent, higher than the Japan's average of 6 per cent. The only area in which Japan's average is higher than Germany's is Urbanization and Construction; the German average is higher in all other 15 areas. In almost all areas, the relative rating of the Japanese and German experts is generally close to the average assessment, and the two countries' trends are quite similar regarding the areas where cultural constraints are seen as a problem. Two areas where there is a slight difference are Urbanization and Construction, in which the Japanese assessment is higher, and Agriculture, Forestry and Fisheries as well as the Medical Care and Health and Production, in which the German estimation is higher (difference more then 5 per cent).

The area in which cultural constraints were indicated most by both Japanese and German experts is Culture and Lifestyles; examples of topics within this area are: the *widespread use of at-home performance of work in general office divisions (excluding interviews and negotiations) based on advances in video telephones, on-line computer systems, and facsimile equipment* (J/G 16-39; Japan: 56%; Germany: 53%), the w*idespread use of an independent sociability training system designed for groups of children of different ages enabling them to be trained in social interactions* (J/G 16-71; Japan: 62%; German: 42%) or the *development of ability-evaluation systems focusing on comprehensive personal ability, such as systems to replace Japan's present system of school entrance examinations* (J/G 16-74; Japan: 48%; Germany: 57%).

In the three infrastructure areas, Japanese experts consistently gave cultural constraints a high rating, while figures of the three advanced technology areas are middle-of-the-road and no specific trend can be seen. Because of the generally higher assessment of cultural constraints in the area of Culture and Lifestyles, this evaluation is excluded from figure 2.7-6.

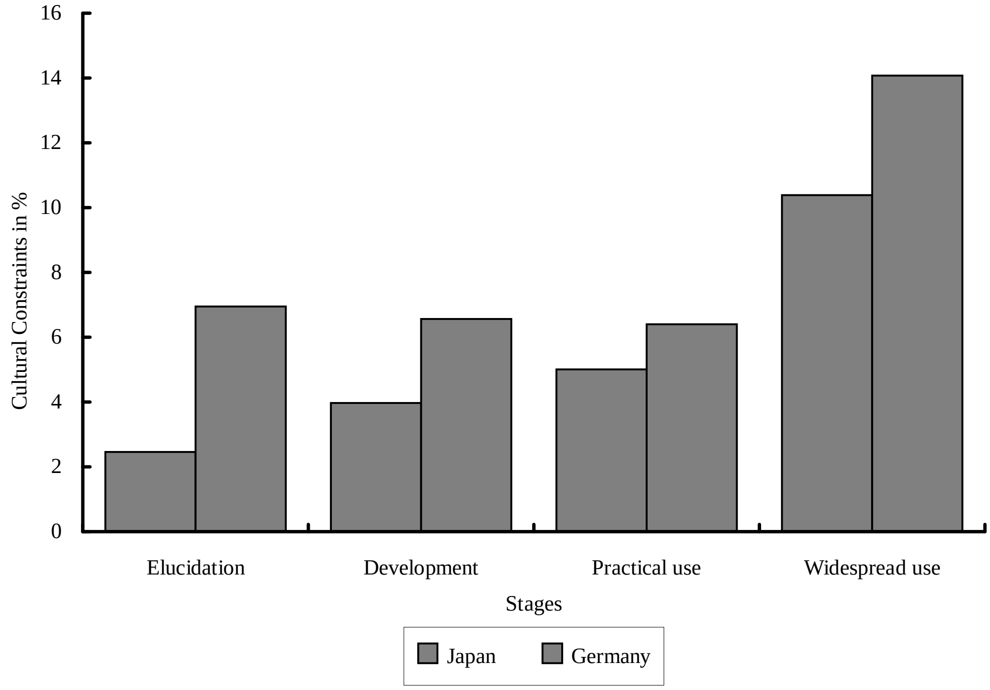
As for technological stages, the assessment of cultural constraints is highest for Widespread Use in both, Japanese and German survey, and in all stages, the German estimation is higher than the Japanese. In the Japanese survey, the evaluation of cultural constraints increases successively in the stages of Elucidation, Development, Practical Use and Widespread Use, and this seems natural since the relationship between technology and society becomes closer as the stages advance. In contrast, the German experts' rating of cultural constraints is practically the same in the Elucidation, Development and Practical Use stages (Figure 2.7-7). This might be due to the fact that the topics were formulated in Japan and there are topics in all phases that are assumed to be culturally hampered in Germany. This underlines the high estimation in Widespread Use where mainly societal and cultural effects hinder the broader use of technology in general.

Figure 2.7-6: *Comparison of the Japanese and German cultural constraints per technological area (The evaluation of Culture and Lifestyle is* excluded *from this figure - in Japan: 18.5%; in Germany: 24.5%. The drawn line passes through the origin and the overall average value)*



Examples of topics in which there is a significant gap between the Japanese and German experts are the *elucidation of human decision making mechanism from the chemical and physical aspects of the brains* (J 2-81/ G 2-82; Japan: 3%, Germany: 70%), the *elucidation and modelling of human memorising, recognising and learning mechanisms to such an extend that allows an application in computer science* (J 2-82/ G 2-83; Japan: 1%; Germany: 33%) or the *elucidation of the molecular basis of animals' actions such as contacting, sexual behaviours and migrations* (J/G 3-93) (J/G 3-93; Japan: 1%; Germany: 26%).

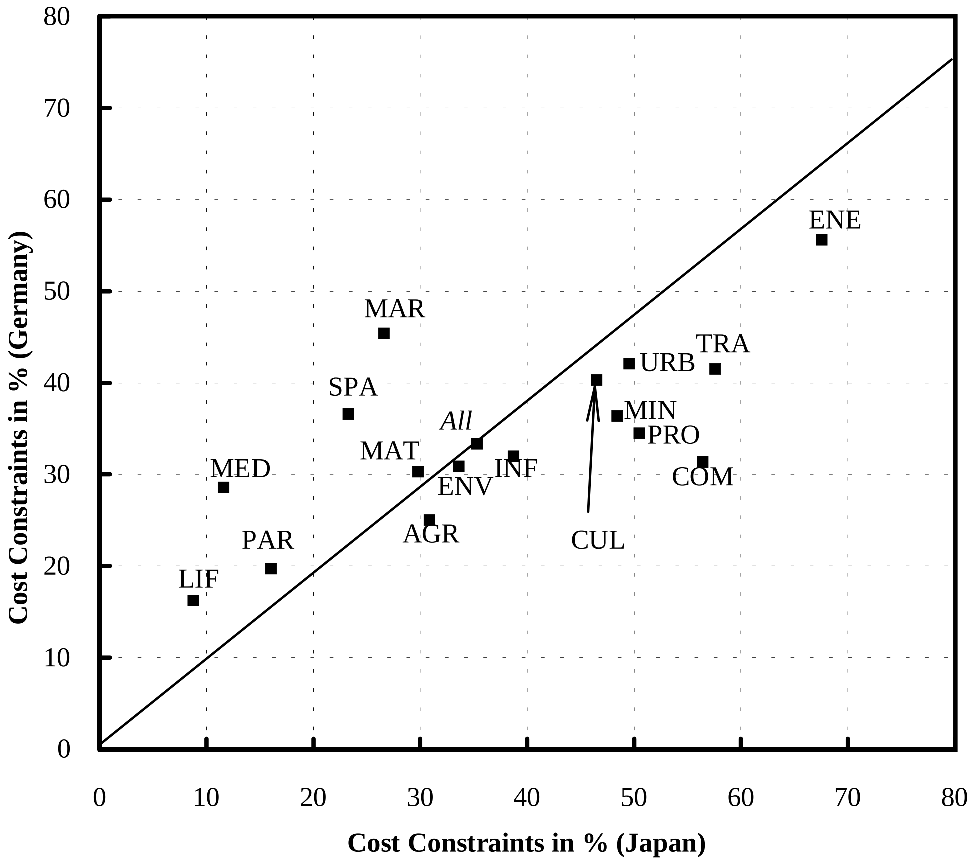
Figure 2.7-7: Comparison of the Japanese and German cultural constraints by innovation phases



2.7.4 Cost Constraints

The average evaluation for cost constraints for all topics is roughly the same in the Japanese survey (36%) as it is in the German survey (33%). The highest percentage for both, Japan and Germany, is evaluated in the technological area of Energy, followed by Transportation and Communications in the Japanese survey, and by Marine Science and Earth Science in the German survey. Overall, many areas are quite detached from the solid line in the figure, indicating a major gap in the opinions of the Japanese and German experts.

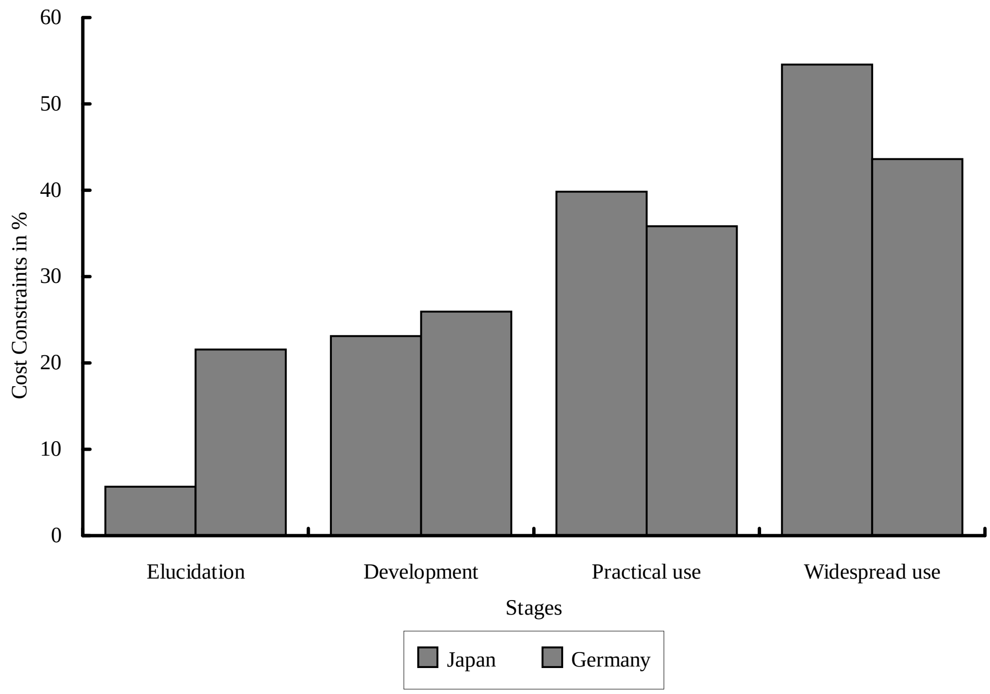
Figure 2.7-8: *Comparison of the Japanese and German cost constraints per technological area (The drawn line passes through the origin and the overall average value)*



Areas in which the cost constraints are higher for Germany than for Japan are Marine Science and Earth Science, Medical Care and Health, and Space. Especially in Medical Care and Health a high percentage of German experts have indicated cost constraints in topics where it has been indicated by very few Japanese experts including the *elucidation of the onsetting mechanism of Alzheimer's disease* (J/G 15-35; Japan: 2%, Germany: 62%), the *practical use of diagnosing methods for determining the level and spread of atherosclerosis focuses by non-evasive methods* (J/G 15-35; Japan: 11%; Germany: 63%) or the *elucidation of the origins of obstructive pulmonary diseases* (J/G 15-6; Japan: 4%; Germany: 54%).

Thus, German experts regard costs as a problem in Medical Care and Health in the early stage, even in the basic research of the Elucidation stage, and here we can see a difference in views between the two groups of experts. On the other hand, the areas in which the cost constraints estimation for Japan is much higher than that for Germany are Communications, followed by Transportation and Mineral and Water Resources, and Urbanization and Construction to make up the three infrastructure areas. The three advanced technology areas are generally near the average (Figure 2.7-8).

Figure 2.7-9: Comparison of the Japanese and German cost constraints by innovation phases

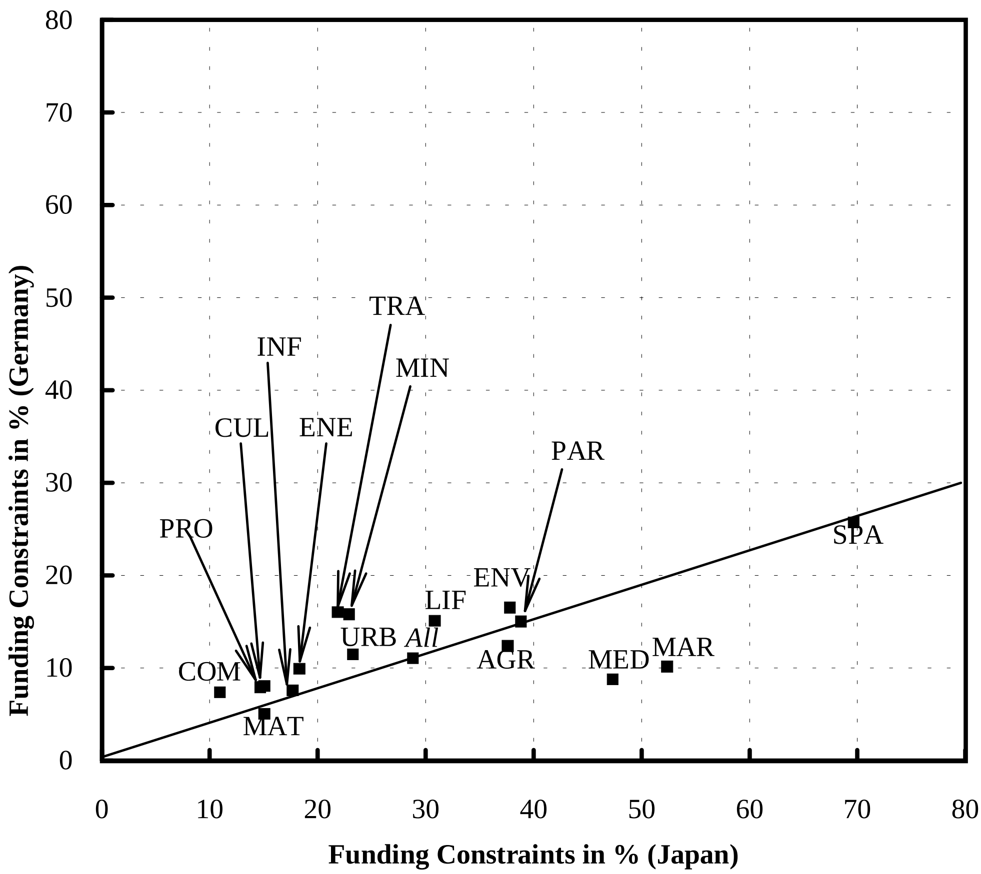


As for technological stages, the cost constraints evaluation increases successively in the stages of Elucidation, Development, Practical Use and Widespread Use for both, the German survey and the Japanese survey; the German assessment is higher in the Elucidation and Development phases and the Japanese assessment is higher in the stages of Practical Use and Widespread Use. The difference is particularly prominent in the Elucidation stage with the Japanese 6 per cent contrasting remarkably the German 22 per cent (Figure 2.7-9). This can be attributed to the previously mentioned difference in views between Japanese and German experts in the Life Sciences and Medical Care and Health areas, which account for more than half of the Elucidation stage topics.

2.7.5 Constraints in Funding

The average for constraints in funding in all topics for Japan is 29 per cent,

Figure 2.7-10: *Comparison of the Japanese and German constraints in funding per technological area (The drawn line passes through the origin and the overall average value)*



considerably higher than the 11 per cent for Germany. Averages for almost all technological areas are distributed generally along the line connecting the origin and the overall average, and only minor differences can be observed in the ranking of the areas.

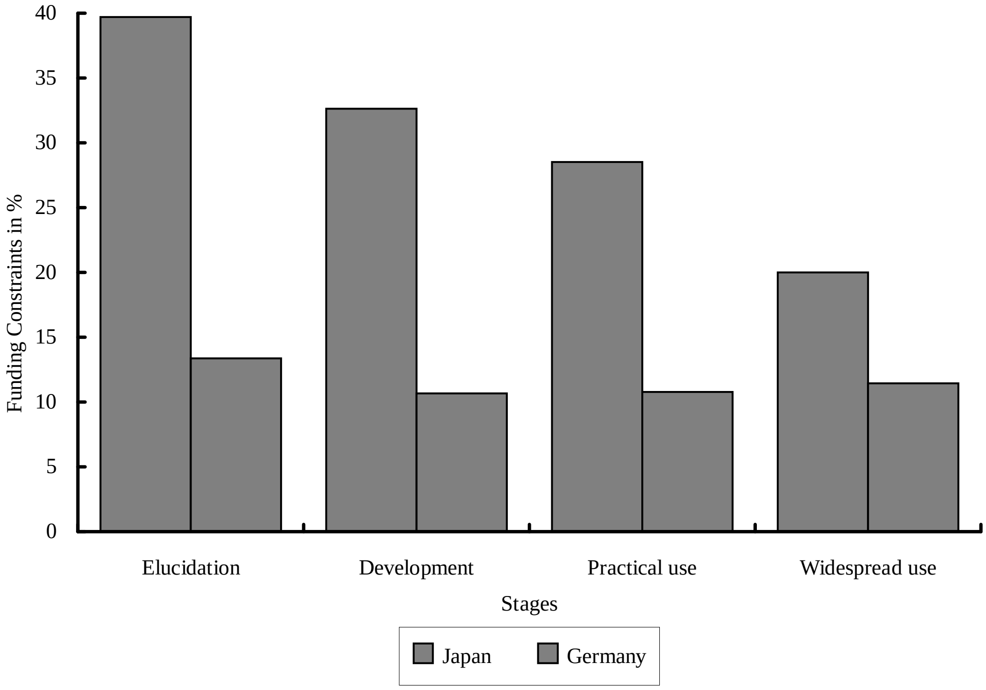
The evaluation of funding constraints is highest in Space for both Japan and Germany but on a much higher level in Japan (43 per cent higher). Japanese experts emphasised funding constraints to a much greater extent than their German counterparts also in Medical Care and Health, Marine Science and Earth Science, Particles, Environment, Agriculture, Forestry and Fisheries and the Life Sciences, while German experts emphasised funding constraints relatively more in Transportation and Mineral and Water Resources compared to the countries average.

In Germany, funding for preventative research (ecological research, research on climatic and environmental change, health research etc.) accounted for 9.1% of the Federal Ministry of Research and Technology budget for 1982, but by 1993 this had leapt to 18.1%, and it is thought that this is one reason why German experts pointed to funding constraints to a much lesser extent than Japanese experts in many concerned areas pertinent to preventive research (Source: Federal Republic of Germany 1993 research year-book).

As for the *relative* assessment on the three advanced technology areas and the three infrastructural areas, in all the infrastructural areas, German experts have indicated funding constraints to a greater extent than Japanese experts (not in absolute percentages), while the three advanced technology areas are generally around the average (Figure 2.7-10).

Regarding technological stages, the German estimations for funding constraints are roughly the same for all stages, whereas the Japanese assessment is highest in the Elucidation stage, which typifies a lack of basic research, then, decreases successively in the stages of Development, Practical Use and Widespread use (Figure 2.7-11). Government funding for basic research is generally higher than funding by the private sector, and as mentioned earlier, the German government's share of overall research spending is about twice that of the Japanese government relative to industrial expenditures (see reference), and more investment is needed for areas in which the outcome and the time of solution is still unknown. This is thought to be one of the reasons that a high percentage of Japanese experts indicated funding constraints in the Elucidation and Development stages.

Figure 2.7-11: *Comparison of the Japanese and German constraints in funding by innovation phases*

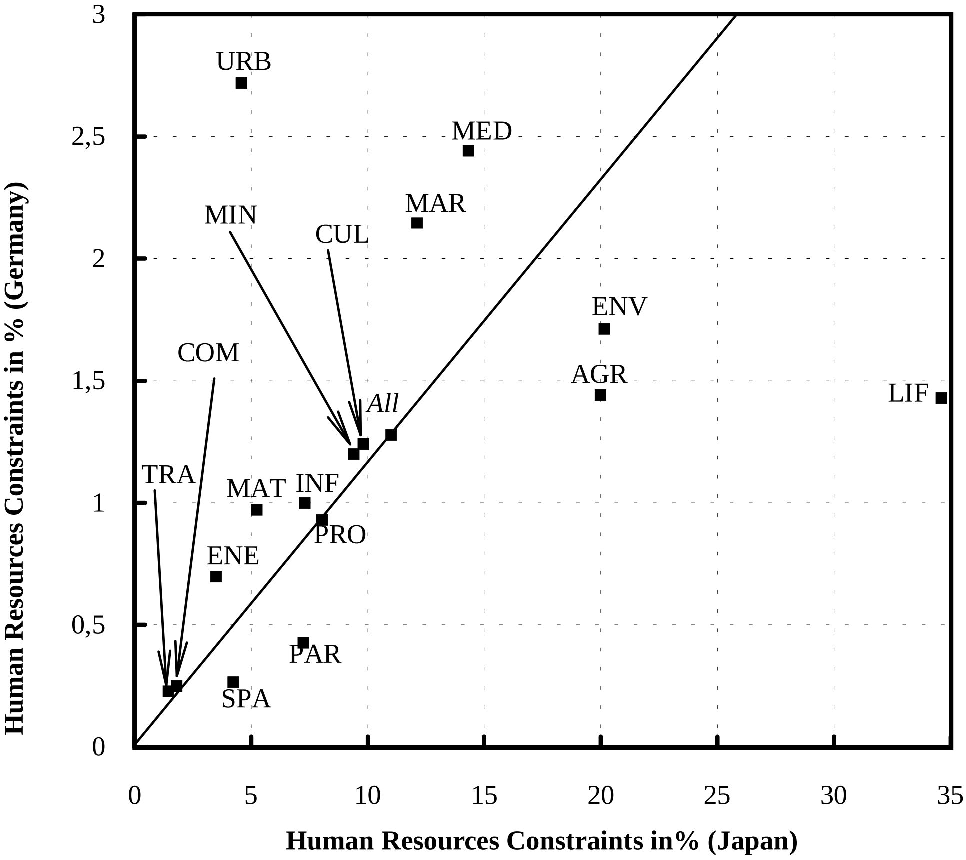


2.7.6 Constraints in Fostering or Securing Human Resources

Constraints in securing human resources were hardly mentioned by German experts in the survey (Japan: 11%; Germany: 1%), and as can be seen in Figure 2.7-12, the scale of the y-axis, which represents the German responses, had to be made smaller than the Japanese x-scale. Here, the graph shall be analysed in the same way as in the other sections, but it is important to keep in mind the extremely low extent to which German experts indicated this constraint.

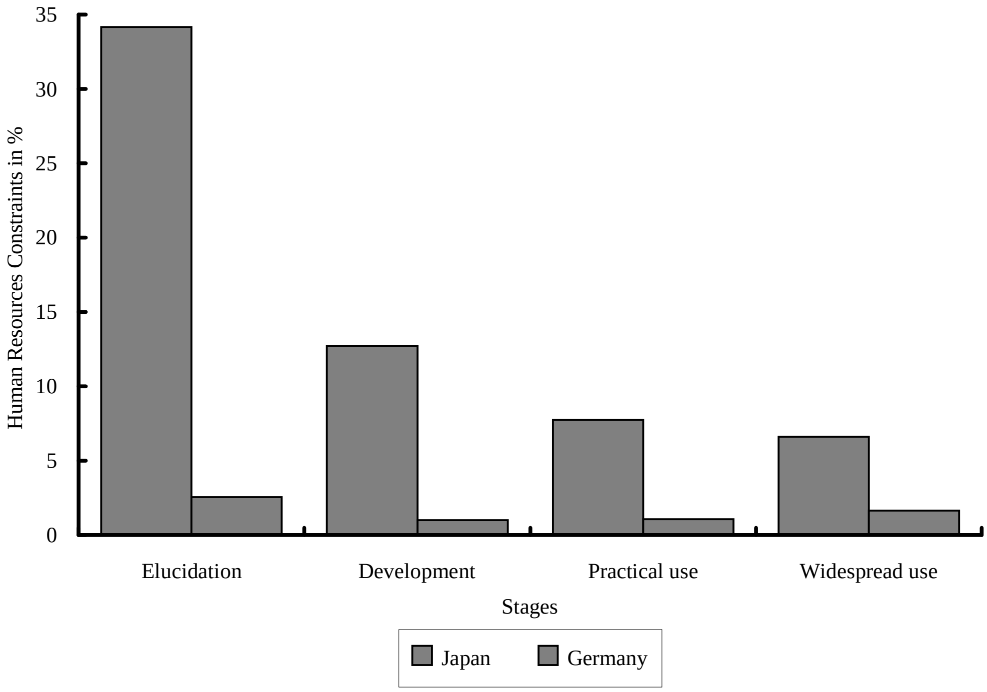
The Japanese percentage is highest in the Life Sciences area, followed by Environment and Agriculture, Forestry and Fisheries. The assessments in these three areas and the areas of Medical Care and Health, and Marine Science and Earth Science are above the average value. What stands out here is that these five areas are all related to life and the environment. And it should be noted that the evaluation is high in technological areas where much is expected in the future and where an concerted international effort is essential.

Figure 2.7-12: *Comparison of the Japanese and German constraints in fostering or securing human resources per technological area (The drawn line passes through the origin and the overall average value)*



As for the three advanced technology areas and the three infrastructure areas, the Japanese estimation is significantly higher than the German one in the advanced technology area of Life Sciences, and although the German estimation is highest in the Urbanization and Construction area, in absolute terms it is still quite low. All other areas are generally near the average line with no major deviations (Figure 2.7-12). The explanation might be the fact that in Germany enough well-educated personnel is available and the scientists of the former East Germany have additionally to be integrated into the unified R&D system. Therefore, many scientists are *unemployed* whereas in Japan at the time, the Delphi questionnaire was sent out, there was a severe lack of personnel in general.

Figure 2.7-13: Comparison of the Japanese and German constraints in fostering or securing human resources by innovation phases



Regarding the technological stages, the Japanese evaluation for constraints in human resources is highest in the Elucidation stage (34%), and this, regarded together with funding, shows that there is a need for the Japanese government to improve measures for promoting basic research (Figure 2.7-13).

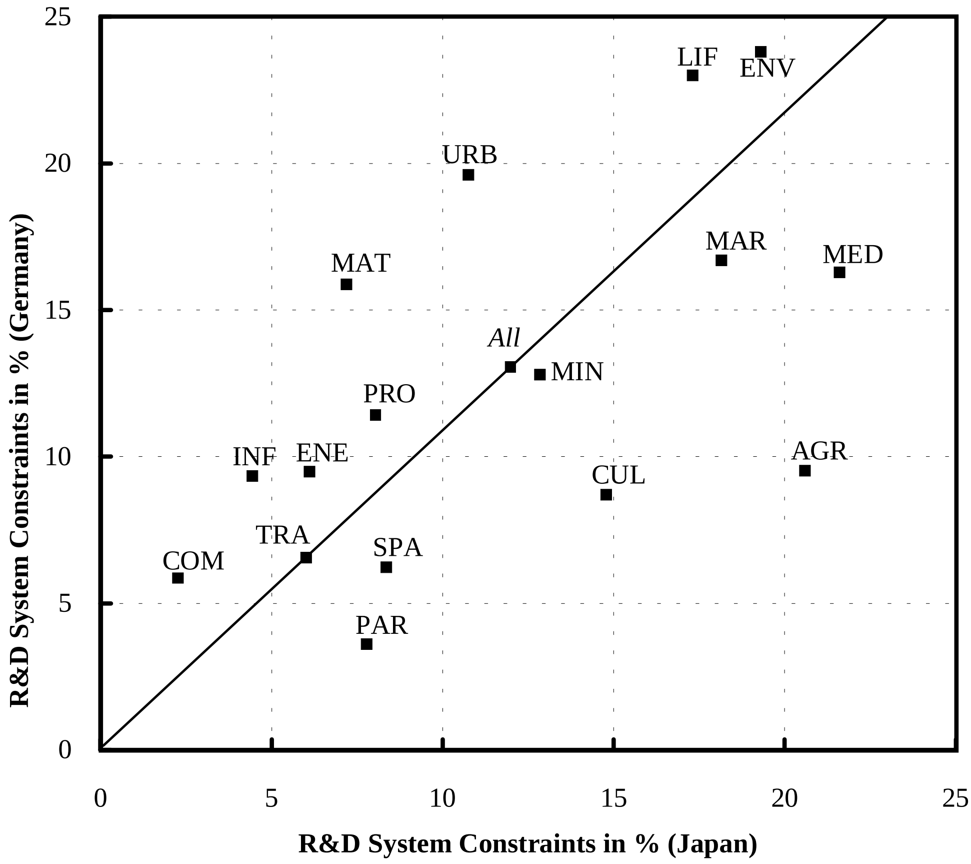
2.7.7 Constraints in the R&D System

Averages for technological areas are scattered around the line connecting the origin and the average of all topics (Japan: 12%, Germany: 13%), indicating quite a high divergence of opinions between Japanese and German experts.

The Japanese percentage is high in the five areas of Medical Care and Health, Agriculture, Forestry and Fisheries, Environment, Marine Science and Earth Science, and Life Sciences, while the German one is high in the three areas of Environment, Life Sciences and Urbanization and Construction. The five areas in which the Japanese estimation is high are the same five areas in which it is high for constraints in securing human resources, mentioned in section 2.7.6, indicating that in the R&D system as well, there are many problems in life and environment related technological areas that must be dealt with.

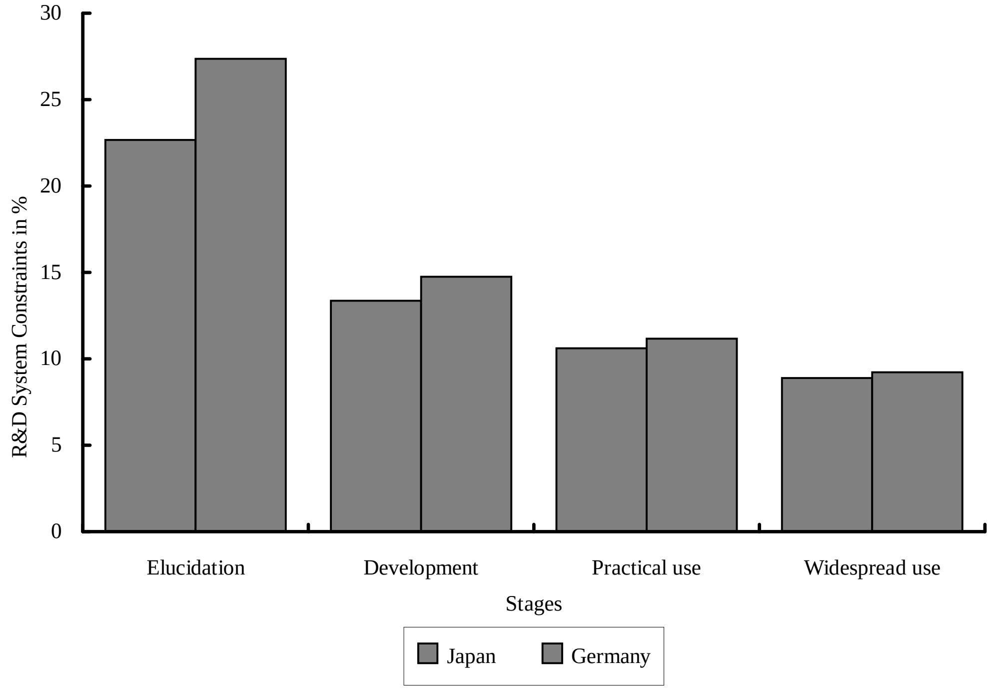
Comparing Japan and Germany in the three advanced technology areas and the three infrastructural areas, it can be observed that the German assessment for R&D system constraints is higher in all advanced technology areas, and that in the three infrastructure areas as well, the German assessment is either higher than or the same (in Transportation) as the Japanese one (Figure 2.7-14).

Figure 2.7-14: *Comparison of the Japanese and German constraints in the R&D system per technological area (The drawn line passes through the origin and the overall average value)*



In all technological stages, the German estimation is higher than the Japanese. The estimation is highest and the country difference is most marked in the Elucidation stage, and from this it can be said that there is a need to upgrade or restructure the basic R&D system, including improving the liaison among research organisations and among researchers in basic research as well (Figure 2.7-15).

Figure 2.7-15: Comparison of the Japanese and German constraints in the R&D system by innovation phases



2.7.8 Summary

To conclude, the constraints on realization of the topics demonstrate individual lacks or strengths of the countries Japan and Germany. Main differences can be found in the technical level and the availability of personnel. The rest category for other constraints is not discussed here in detail. It may suffice to recall (other constraints are not discussed here) that German experts used this category more often than Japanese indicating that an important constraint category is missing. From the comments of experts it is known that in most cases, this points to missing public acceptance of new technology as the most important hindrance. Public acceptance is not equal with cultural factors as lack of acceptance is generally not experienced for the society as a whole but for certain large groups.

2.8 Conclusions on the Macro Level

As stated in Chapter 1, the basic character of the respondents from the two countries, such as age composition, occupations and occupational categories, are similar; and, as analysed in chapter 2.1, the respondents' degree of expertise, which has a considerable effect on the standard of the forecast results under the Delphi method, is also quite similar. On these premises, a comparative analysis of importance, realization time, necessity of international co-operation, the R&D level, and R&D-related constraints yielded the following results.

As for importance, although the overall average value was higher for Japan than for Germany, there is a fair degree of conformity between the two countries in the assessed importance of individual topics. Concerning the realization time, there is close conformity in overall average values, and there are also strong trends towards conformity in the various innovation phases and the individual topics. The conformity seen in such key parameters as importance and forecasted realization time in technology forecasts backs up the view that any differences between Japan and Germany are due to other parameters.

Table 2.8-1 lists the characteristics of technological areas for both countries from the viewpoint of the degree of importance and the realization time. The degree of importance is compared with the average estimation, here, and has been divided into three classifications: Higher importance in Japan (which means higher than the average in Japan), roughly equal importance and higher importance in Germany (in relation to the German average).

The realization time has been structured similarly. As becomes evident in the table, there is a substantial difference between the Japanese and German estimations in three areas of Space, Materials and Processing, and Culture and Lifestyles. One feature of the Culture and Lifestyles area is that topics contain many cultural constraints, which is due to the characteristics of the topics, and as for Space, as mentioned earlier, Germany is proceeding with space research and development as a member of the ESA, whereas most of Japan's Space research and development is carried out independently, so that the gap between the two countries is quite prominent, here.

Table 2.8-1: Classification of technological areas by the degree of importance and the realization time

		Importance		
		Relatively high in Japan	**Almost the same**	**Relatively high in Germany**
Time of realization	**Relatively late in Japan**	**SPA**	**MAR, COM**	**MAT**
	Almost the same	**MIN, AGR**	**LIF, PAR, ENE, URB**	**ENV, MED**
	Relatively late in Germany	**CUL**	**INF, PRO, TRA**	

In the three areas of advanced technology (Materials and Processing, Information and Electronics, and Life Sciences), German experts regard Materials and Processing as more important than their Japanese colleagues and are more optimistic about realization than the Japanese experts, while the Japanese experts think that realization will be earlier in the Information and Electronics area. This seems to reflect the industrial specialisation of the two economies. The development of new material and process engineering is to a large share associated with the chemical industry which is one of the strong industries within Germany (see e.g. Porter, 1990). On the other hand, Japan is among the world leaders in electronics and her electronic industry is considered as much stronger than the chemical sector (see e.g. Kodama, 1991).

The Life Sciences may also be associated with chemical industry along with food, agricultural or medical sectors. There is no notable gap in the area of Life Sciences. Japanese and German experts have different opinions about international co-operation in three areas: in the Life Sciences area, the Japanese experts, and in the Materials and Processing area, the German experts think there is a higher necessity for international co-operation.

On the other hand, in the three infrastructure areas (Urbanization and Construction, Communications and Transportation), both groups of experts share similar views about the degree of importance, however, the German experts forecasted an earlier realization time in Communications, while the Japanese experts forecasted an earlier realization time in Transportation. In all three areas, German experts assume that there is a higher need for international co-operation than the Japanese experts do.

Overall, German experts estimate international co-operation to be more important than Japanese experts do; however, the trend for Japan and Germany generally conforms in each of the areas, and there are no major differences. On the whole, it is thought that the differences are a reflection of the geographical environment of the two countries. This is underlined in the analysis of technological stages by the fact that the perceived necessity of international co-operation for the topics in the Widespread Use stage is of considerably more relevance in Germany than in Japan. In a further reflection of this, although there is little difference between the two countries in the three advanced technology areas, German experts place more importance on international co-operation in the three infrastructure areas than Japanese experts do.

In the evaluation of the current R&D level, Japanese experts tend to be very conscious about Japan's low level of basic research, which typifies the Elucidation stage, and this can also be seen clearly in the German experts' assessment of Japan's current R&D level. The German experts' assessment of their own R&D level in the Elucidation stage is generally the same as in the other stages. This is clearly reflected in the constraints in funding and constraints in fostering or securing human resources. The Japanese evaluations for these two constraints are extremely high in the Elucidation stage, but lower in the Practical Use and Widespread Use stages. This difference between the stages is not as evident in Germany's case. From this, it can be concluded that in Japan, there is a wide gap between those topics on basic research, which is carried out mainly by the government, and projects on industrial development, which is carried out mainly by the private sector.

Regarding institutional constraints, the Japanese estimations in the Widespread Use stage are much higher than the corresponding German assumptions, revealing that, in Japan, social regulations often become a problem in the actual application of science and technology within society. This is an interesting issue which should provide a warning to those who believe that Germany is disadvantaged in the application of new technologies compared to Japan because of a too strict legislation.

On the other hand, the high German assumption on cost constraints in the Elucidation stage contrasts with the extremely low Japanese estimation, and this is thought to show that in the basic research stage as well, in Germany, there is a high awareness regarding the expenditures and the expected feasibility of applying science and technology within society. A comparison of the three advanced technology areas and the three infrastructure areas reveals that, while there is no major difference between Japan and Germany in the advanced technology areas, in the infrastructure areas, the Japanese assumptions on institutional, cultural and cost constraints are estimated as being relatively higher than the corresponding German evaluations.

In an overall comparison of all variables in the two groups of technological areas mentioned above, in both Japan and Germany, more differences can be seen in technologies that are connected with the infrastructure. These technologies are more closely linked to society and the economy than the advanced technologies, whereas no major differences can be detected in the advanced technology areas, revealing that the relevance of science and technology for the society differs.

3 Cross Comparisons on the Macro Level

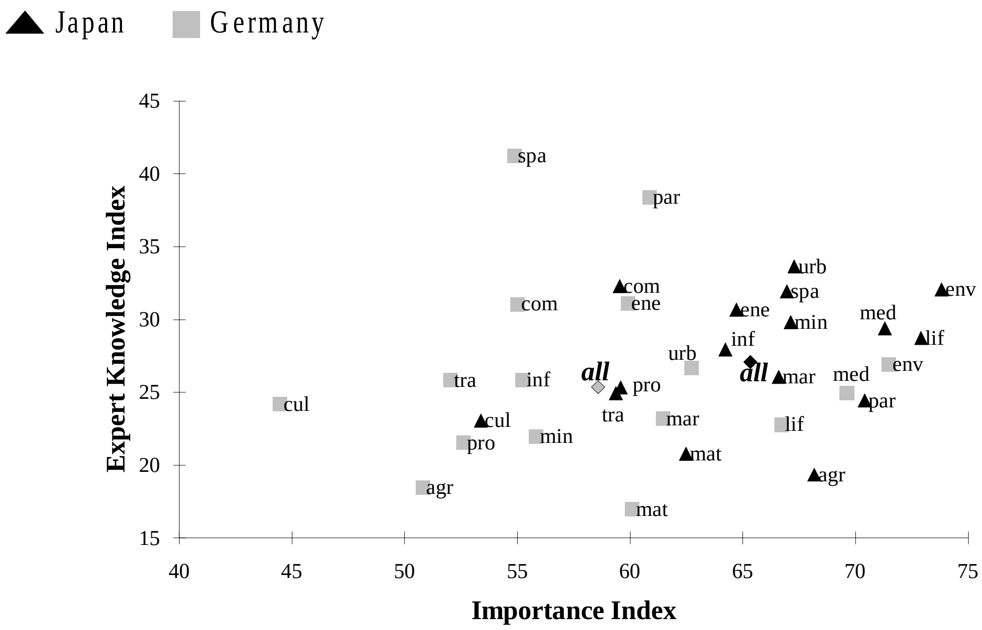
3.1 Comparing Expert Knowledge with Importance

A general assumption is that experts tend to have a positive bias towards their own field of expert knowledge (see chapter 1.1). Indeed, if the experts' knowledge and the assessment of importance per topic are correlated, a good correlation for Japan and Germany is found: The experts consider these innovation projects, which they know better, to be more important. No significant correlations could be shown, however, on the level of the 16 technological areas as topics of high and low expert knowledge are mixed. Comparing the expert knowledge of the Japanese and German participants in the Delphi survey and their estimation of the importance of the examined topics *per technology area*, there are relatively small differences.

In the German survey, importance and expert knowledge are judged as being relatively independent of each other. The technological fields of Space (spa) and Particles (par) seem to be exceptions but this is due to the high estimation of the degree of expert knowledge as discussed in chapter 2.1. Although the degree of knowledge is so high, these areas are not regarded as very important. The fields with a higher rate of importance are - as discussed in chapter 2.2 - Life Sciences (lif), Environment (env) and Medicine (med) but in these cases, the expert knowledge is average, so that a bias in the assessment cannot be assumed.

The Japanese estimation reveals a stronger relationship between expert knowledge and importance than the German one does. Questions with a relatively high estimation of experts' know-how are also considered to be more important, e.g. Urbanization and Construction (urb), Space (spa), Energy (ene), Environment (env), Mineral and Water Resources (min), Medicine (med) and Life Sciences (lif). In these technological areas, a certain bias of the experts can be assumed whereas in the fields of Marine Science and Earth Science (mar) and Agriculture, Forestry and

Figure 3.1-1: *Japanese - German comparison of expert knowledge index versus importance per technological area*



Fisheries (agr), the importance is rated similarly high, although the knowledge of the participants is low.

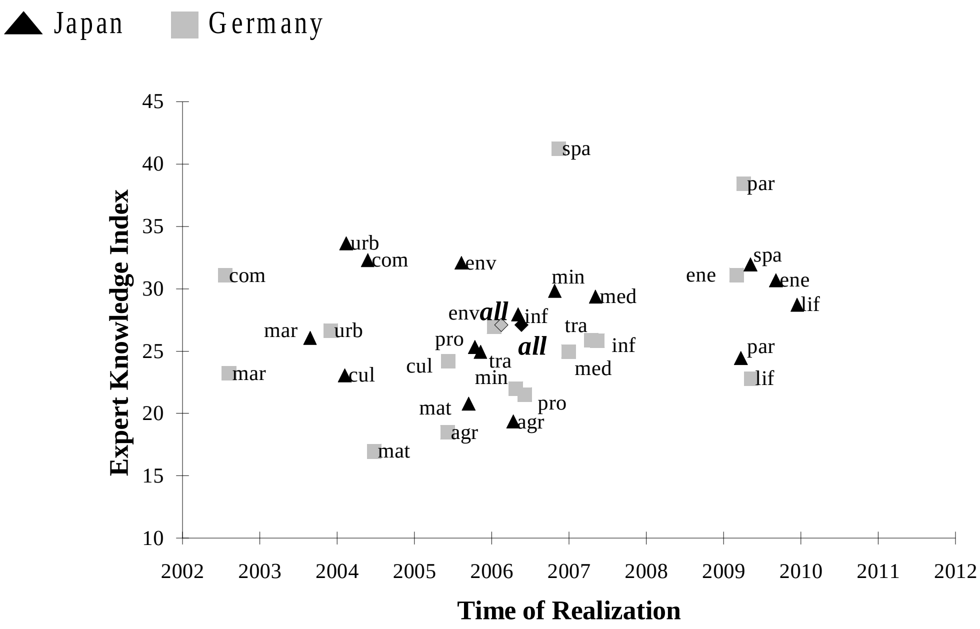
Regarding the technology development phases of the topics, almost the same patterns can be observed in Japan and Germany with a generally higher level in Japan, because the average of importance was higher there in all technological fields, and in topics dealing with Elucidation a higher degree of expert knowledge is shown (see chapter 2.1 and 2.2).

The absence of a bias towards the expert's own working field at the level of larger technology fields does not invalidate the problem. An expert may prefer his or her own discipline or sub-field, e.g., the nuclear physicist, nuclear energy and the semiconductor physicist, photovoltaic energy. But on the level of the total energy field, however, these possible preferences cancel out.

3.2 Comparing Expert Knowledge with Forecasted Time of Realization

In this chapter, the expert knowledge and the forecasted time of realization are compared. Concerning all technological areas, no significant difference could be observed by applying a regression calculation.

Figure 3.2-1: Japanese - German comparison of the expert knowledge index versus time of realization by technological areas



Although the experts' knowledge is different in some cases (see chapter 2.1), the forecasted average time of realization in both countries is nearly the same in fields like Materials and Processing (mat), Life Sciences (lif), Particles (par), Marine Science and Earth Science (mar), Mineral and Water Resources (min), Energy (ene), Environment (env), Agriculture, Forestry and Fisheries (agr), Production (pro), Urbanization and Construction (urb), and Medicine (med) (see also chapter 2.3). The largest difference between Japan and Germany can be seen in Space (spa), but does not exceed 3 years. The more knowledgeable German experts are also more optimistic.

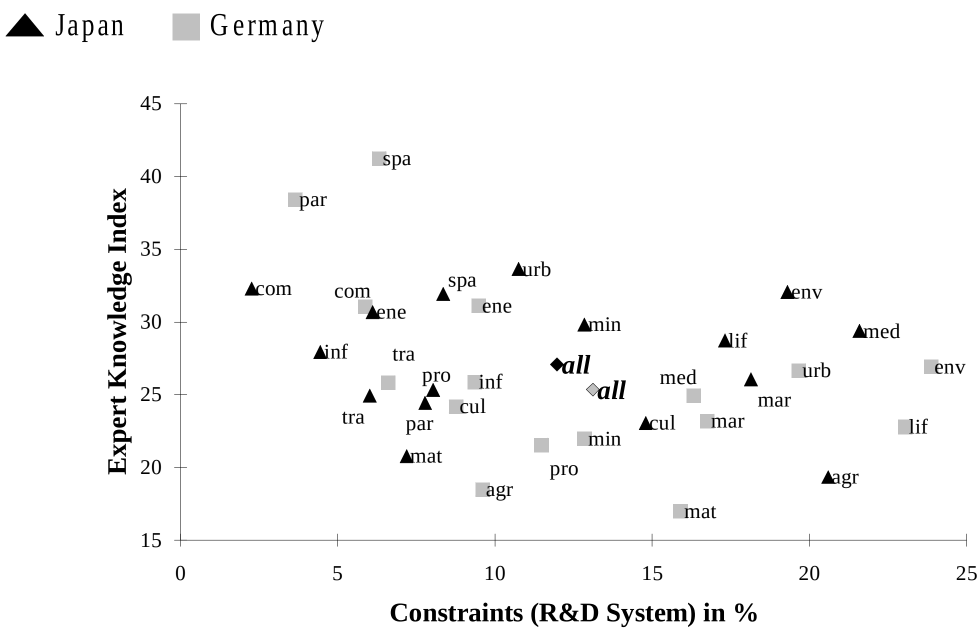
Concerning the technology development phases, almost no difference is noticeable. As discussed in chapter 2.1, the respondents' knowledge does not differ very much. The same is true for the realization time where the differences in estimation are not larger than two years (see also chapter 2.3).

3.3 Comparing Expert Knowledge with Constraints on Realization

The Delphi survey asked for technical, institutional, cultural, costs and funding constraints as well as for problems with human resources, the R&D system and other constraints on realization.

Comparing the expert knowledge versus the above mentioned constraints on realization, no correlation is visible. Regression calculation did not show any significance between the criteria. Therefore, in this report, only one example is discussed to represent the others.

Figure 3.3-1: Japanese-German comparison on expert knowledge versus the constraint "R&D system"



In this chart (Figure 3.3-1), the estimation of expert knowledge versus the constraint on "R&D system" is similar in both countries. As already discussed in 2.7, there are differences between the countries of more than ten per cent in the field of Agriculture, Forestry and Fisheries (agr) but the degree of the respondents' know-how is the same: it is quite low in both countries and cannot explain the different assessments of the R&D infrastructure. Although the R&D infrastructure of Agriculture, Forestry and Fisheries (agr) is *not* considered a major problem in Germany, in contrast to the assessment in Japan, the knowledge available among the German Delphi respondents is nevertheless as low as that in Japan.

Concerning the R&D system, there are some technological fields with a very favourable assessment, e.g. Communications (com), Information and Electronics (inf) as well as those with an unfavourable estimation such as Environment (env), the already mentioned Agriculture, Forestry and Fisheries (agr) or Medical Care and Health (med) (both in Japan only) and Life Sciences (in Germany only). However, this assessment, favourable or not, is not related to the knowledge base incorporated into the Delphi surveys. Extreme judgements in Germany were made in the fields of Space (spa) and Particles (par) with a higher expert knowledge but a favourable evaluation of the R&D infrastructure.

Regarding the technology development phases, almost the same structure can be observed (charts are not included in this report). Although the expert knowledge is quite similar in both countries (see chapter 2.1), the technical constraints are evaluated as being much higher in Japan (see chapter 2.7). The differences do not result from the correlation of the experts' know-how and constraints but from the different evaluation of constraints only (see chapter 2.7).

3.4 Comparison of the Importance and the Time of Realization

Several hypotheses regarding the relationship between the importance of the various technological topics and the period needed for their realization can be established. The first is that a major effort in development is expected to be made in technologies which are regarded as important by many experts, resulting in the realization within a set period. Conversely, R&D is not expected to be carried out actively in technologies whose importance is considered to be low, so that the time of realization will be much later.

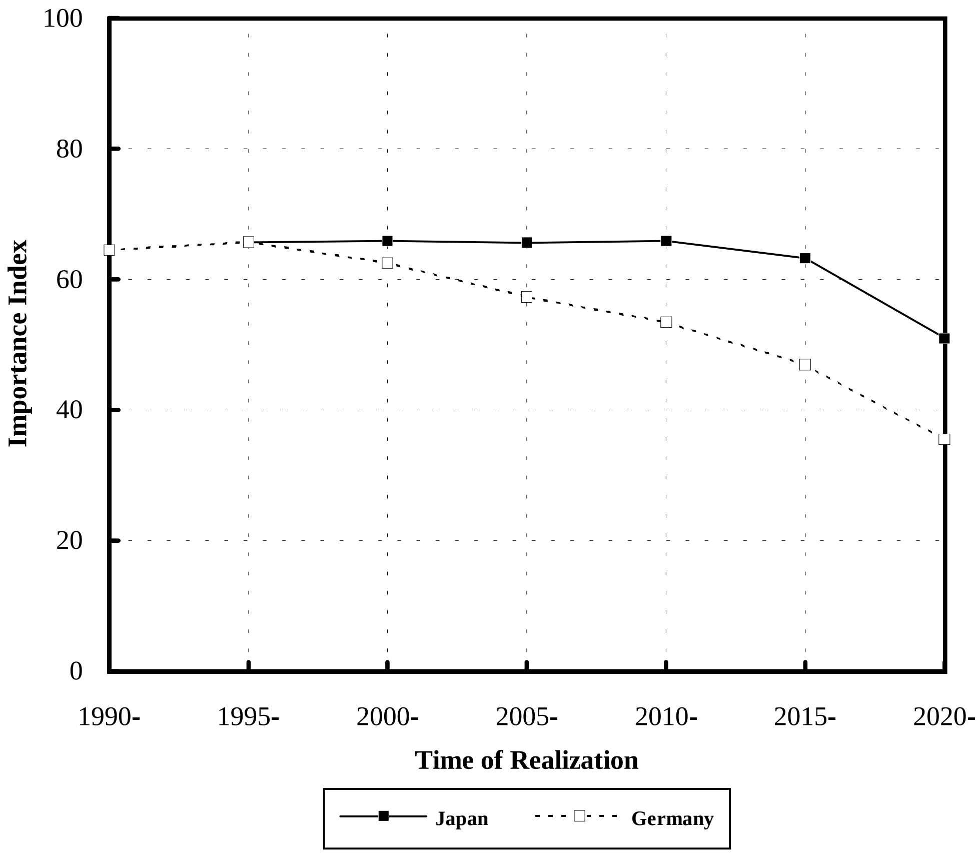
The second is that those technologies which will take a long time to be realized so that forecasts are very difficult to make and, in view of their lack of any apparent urgency, do probably not appear to be highly important to many experts. On the other hand, it is also possible that some technologies that are likely to be realized soon are also considered to be of low importance.

The third is the effect of differences in national circumstances. That is, countries with a tradition in and the potential for long-term R&D may asses technologies as important even if their development requires a long period of time, or countries which place importance on the effectiveness of R&D may emphasise technologies which can be realized in the mid-term scale and from which results can be expected.

Figure 3.4-1 shows the Japanese and German data on importance and time of realization from this point of view. As can be seen from the figure, in Japan, the degree of importance is very uniform except for topics whose forecasted realization time is 2020 or later.

On the other hand, in the German survey, we can observe the trend that the longer the research takes, the lower the importance given to it. These data alone do not allow to draw any conclusions as to which of the hypotheses mentioned above apply to which topics, but the data do imply that there are differences between the views of Japanese experts and those of German experts towards long-term innovation. Japanese seem to put more emphasis on long-term visions, vague as they may be.

Figure 3.4-1: *Comparison of forecasted year and importance (Japan and Germany) (The importance index (Japan) 1990- are omitted in this figure because the number of corresponding topics is zero)*



3.5 Comparison of the Time of Realization and the Time Variance

In the technological forecasts using the Delphi method, the views of the experts are directed primarily to forecast the realization time of each topic, for calculations see chapter 1.5. In cases, where the forecasted realization time is relatively near, there should hypothetically be a good degree of conformity among the views of the experts, but we surmised that, as the forecasted realization time becomes longer term, the degree of conformity gradually drops. To indicate to what extent the respondents' views about the forecasted realization time conform, the difference between the forecasted years of the respondent were calculated on the 1/4 point and on the 3/4 point of all responses. This difference is called the "time variance".

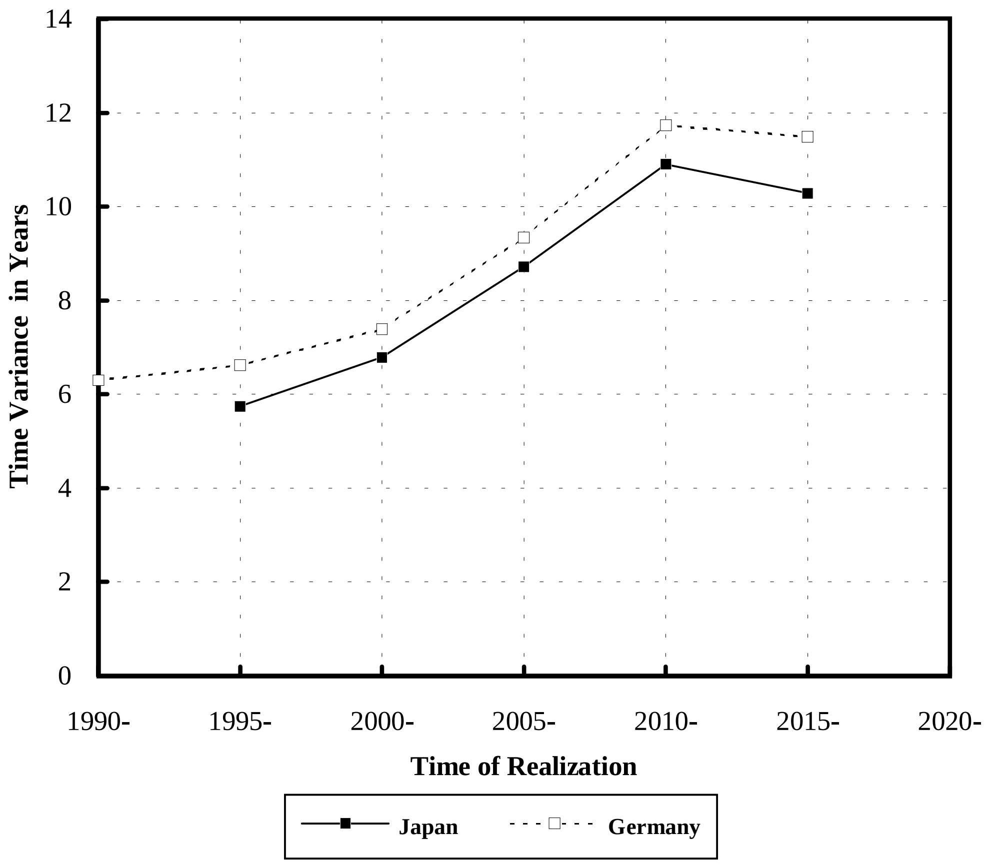
The overall period was divided into five-year blocks based on the forecasted realization time of all topics, then, the average time variance value for topics in each block was calculated as shown in Figure 3.5-1. With the realization time extended to 2015, we observed that the later the forecasted time, the larger the time variance for both Japan and Germany, and this supported what has been stated earlier.

In all blocks, the time variance of the German estimation is larger than that of the Japanese, and the average time variance for all topics is 9 years for Germany, compared to 8 years for Japan.

After calculating the average time variance value for each technological area, all areas in ascending order were arranged according to the calculated value as shown in Table 3.5-1. The area, in which both Japan and Germany have the smallest time variance, i.e. their views show the closest conformity, is Communications, while the area with the largest time variance, i.e. their views tend to show the greatest divergence, is Life Sciences.

Of the five areas on top of table 3.5-1, in which Japan and Germany have a small time variance, the three areas of Communications, Space and Urbanization and Construction are common to both countries, while of the five areas at the bottom of the table, in which there is a large time variance, the four areas of Life Sciences,

Figure 3.5-1: *Relation between the forecasted year and the time variance (Japan and Germany) (The time variance (Japan) 1900- is omitted in this figure because the number of corresponding topics is zero. 2020- has no significance)*



Mineral and Water Resources, Agriculture, Forestry and Fisheries and Medical Care and Health are common to both countries.

Marine Science and Earth Science is slightly different from all other areas in that in the Japanese survey, it is one of the five areas in which there is a small time variance and thus, agreement among the experts, whereas in the German survey, it is one of the five areas in which there is a large time variance demonstrating disagreement. These two areas are conspicuous also in other aspects. Some explanations may be found in chapter 3.6.

With the exception of Marine Science and Earth Science, the size of the time variance for corresponding areas in the Japanese and the German surveys tends to be similar. From this, we can infer that the extent to which expert views do coincide within a technological area is greatly influenced by the characteristics of the topics in the specific area in question, and are only marginally influenced by differences in the socio-economic environment.

Table 3.5-1: The Japanese and German time variance per technological area

Japan			Germany	
Field	J-TV		G-TV	Field
ALL	8		9	ALL
COM	6		7	COM
CUL	7		7	PAR
URB	7		8	TRA
SPA	7		8	URB
MAR	7		8	SPA
INF	8		8	MAT
MAT	8		8	CUL
PRO	8		9	PRO
TRA	8		9	INF
ENE	8		9	ENV
PAR	8		9	ENE
ENV	9		9	MIN
AGR	9		9	AGR
MIN	9		10	MED
MED	9		10	MAR
LIF	10		10	LIF

3.6 Comparing Certainty with Time of Realization Variance

Two different measures for the precision in determining the time of realization are available from the two Delphi surveys. One is the direct estimation of precision or *certainty* (see chapter 2.4) by the experts per item. They judged their time estimates insofar as they mentioned their ability to determine the time of realization more precisely than in five year steps, with a precision of about five years or with a lower precision than five years. From this, an index was calculated. On average, the index is somewhat below 40 which means that the experts estimated the average precision at somewhat more than, but close to 5 years.

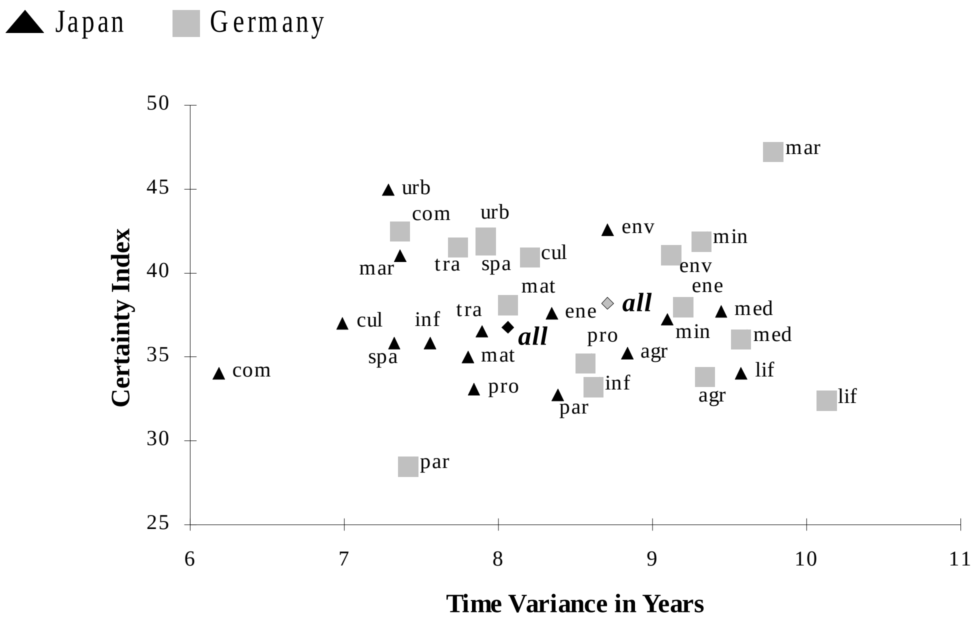
The other precision measure is derived from the distribution (quartiles) of answers per topic, the *time variance*. Two factors influence this measure. One is, of course, the precision or certainty as indicated above, the other is systematic disagreement amongst the experts per item (see chapter 2.4). If there is no systematic disagreement only the stochastic variance should occur and be equal to the certainty measure.

From figure 3.6-1, it is obvious at first sight, that there is considerable systematic disagreement among the experts within each country. Time variance is between 7 and 10 years in most areas. The degree of certainty asked for the three categories high (more precise than the five years step), medium (in the five year phase that is chosen) and low (not in the phase of five years phase chosen) varies between 33 and 43 (with some outliers). This corresponds to an uncertainty of more than five years, respectively. This is a clear indication, that only some parts of the time variance are explained by the stochastics of possible forecast precision and the remaining variance is due to systematic disagreement between (groups of) experts. This is observed both in Japan and in Germany.

Comparing the overall estimation of certainty and time variance, no major differences between the Japanese and the German experts' estimation can be seen. A regression calculation shows no significance that could be mentioned on the macro level of technological areas. It was expected that the higher the certainty, the smaller the time variance, but no such effect occurred. Thus, the technological areas may be differentiated *only* by the extent of systematic discord amongst the

Delphi respondents and hardly by different forecast precision.

Figure 3.6-1: Japanese - German comparison of certainty on the expert's foresight and the time variance of realization per technological area



The technological area with the highest certainty also has the broadest time variance which reflects the experts' discord (Marine Science and Earth Science, mar) in the German forecast. In other areas with a higher degree of certainty, there is a mixed variance in the estimation of the realization time. In 14 of the 16 technological areas (exceptions are Transportation and Particles), the time variance is smaller in Japan than in Germany. In most fields, the time variance is between 7 and 10 years. Only in Communications (com) in Japan, the time variance is less than 7 years and for Life Sciences (lif) in Germany, it is larger than 10 years.

For most of the Japanese technological areas, a somewhat lower degree of certainty than for the German is evaluated (indices between 32 an 39, the exceptions are Urbanization and Construction, Marine Science and Earth Science, and Environment), but still time variance is often *smaller* than in Germany which should result in higher confidence. This is underpinned by the area of Environment, where the Japanese judge a high precision of the forecast but a quite large time variance and thus, low confidence. Exceptions to this puzzle are Urbanization and

Construction (urb), Marine Science and Earth Science (mar) both with high indices of certainty (above 40) and a relatively small time variance. In the German Delphi survey, the certainty is mostly between an index 32 and 42 which is a broader variety of estimations. Exceptions, here, are the already mentioned fields Particles (par) with a low degree of certainty but a relatively small time variance and Marine Science and Earth Science (mar) with a large time variance in the German Delphi and hence, estimated differently from the Japanese Delphi, in which the time variance is lower than 8 years.

The technology field with the lowest certainty (Particles, par) in both countries has a low or medium time variance. In this case, the very closed science community shares its knowledge and judges with the same background in mind but is uncertain about the time scale or might be cautious. Life Sciences (lif) have in both countries a low degree of certainty and a lot of disagreement resulting in a broader time variance of more than 9 years for this technological field in Japan and a slightly higher judgement for time variance in Germany. The contribution of systematic disagreement is very small in the Communications field in Japan and larger in Agriculture, Forestry and Fisheries, according to this type of analysis with all its limitations.

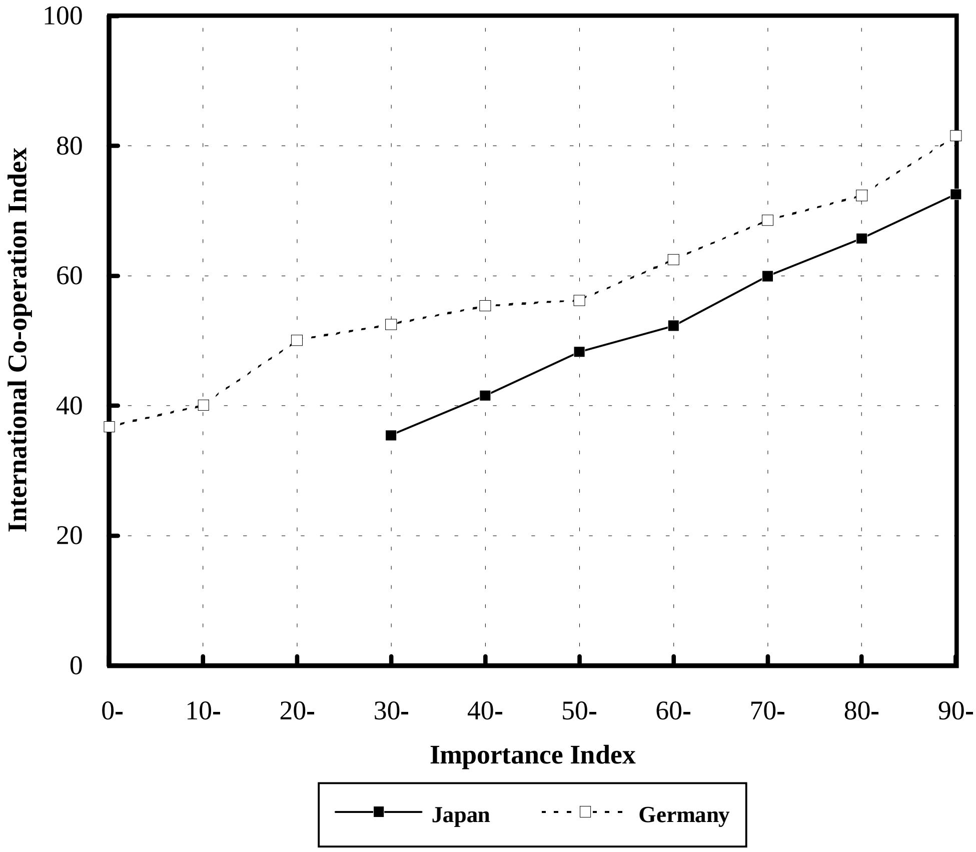
Although the thesis of "the higher the certainty, the smaller the time variance" is disproved on the *macro level* of technological fields, this result is not surprising. Regarding the opinions of the different science communities on certain technologies, there are "schools" which are supportive and estimate an early realization time and others which oppose this technology. The adverse experts judge a technology as unreasonable or as "science fiction" (as many of them commented) which cannot be realized at all. One example is the technological area of energy. There are experts on solar energy who foresee the solar cell solutions as very early (and important) topics but ignore atomic power or nuclear fusion. In the overall result, which is the sum of both opinions, a larger time variance for this specific area is calculated. If all topics are considered one by one, then indeed, higher certainty coincides with smaller time variance for the Japanese and German data set.

Therefore, statements on certainty versus time variance can only be very vague because they represent an average of all topics in the specific technological area which, for example, in Culture and Lifestyles (lif) can be themes such as education as well as safety at home, brain mechanisms, robots or environmental issues. For an in-depth analysis, the individual topics and the answering science community - one by one - would have to be taken into account. However, for reasons of securing personal data, it is not possible to re-identify the respondents of the individual questionnaires in this report. With respect to the technological development phases, the independence of precision estimation and observed variance in time is confirmed. We omit the details.

3.7 Comparison of the Necessity for International Co-operation with the Importance

The average index for the necessity of international joint development concerning all topics is higher in the German survey than in the Japanese: 61 for Germany compared to 54 for Japan. On the other hand, the average importance index for all topics is higher in the Japanese survey than in the German survey: 65 for Japan compared to 59 for Germany.

Figure 3.7-1: Relationship between Importance and International co-operation (Japan and Germany) (As the number of corresponding topics is five and less, international co-operation (Japan) 0-, 10-, and 20- is omitted in this figure)



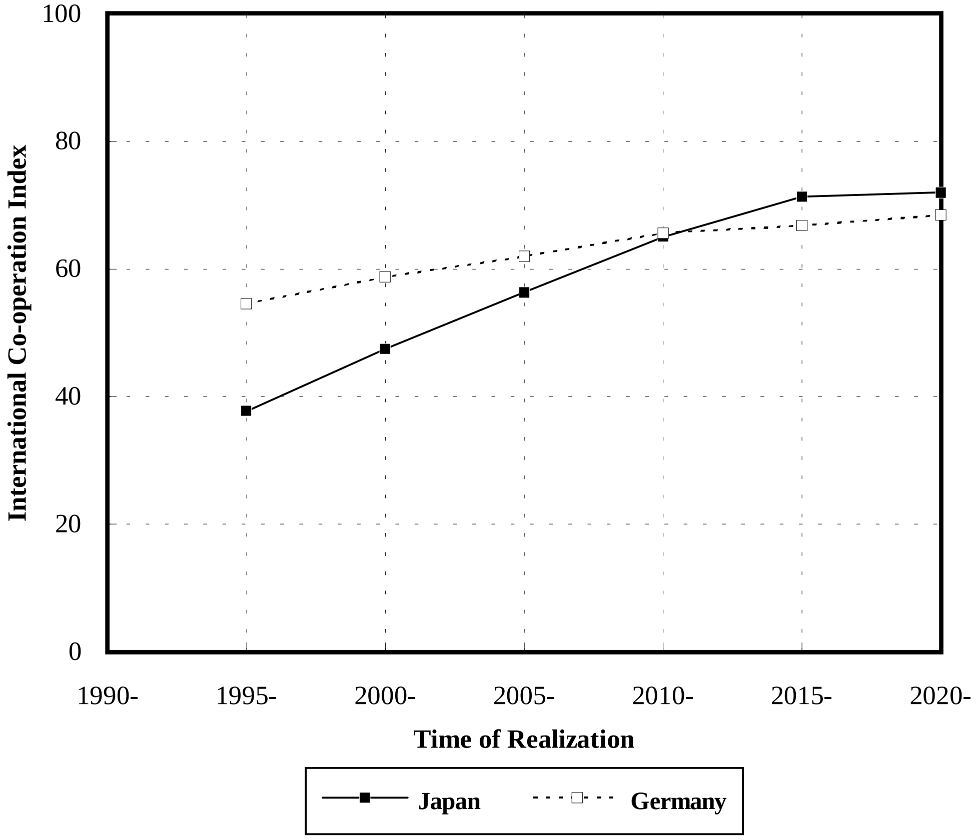
Science and technology today is very international in nature, therefore a correlation between the importance and the necessity for international co-operation can be expected for both countries. Such a correlation exists, indeed, and is shown in Figure 3.7-1.

The overall trend is that experts in Japan and Germany assess that there is a strong need for international co-operation in projects with a high degree of importance. The graphic shows a significant linear correlation. This demonstrates the awareness of the experts in both countries that in present-day society the more important the topic, the more difficult the realization is if tackled by a single country in isolation, and thus the stronger the need for international co-operation.

3.8 Comparison of the Necessity for International Co-operation and the Estimated Time of Realization

In this chapter, it is analysed whether there is a correlation between the necessity to co-operate internationally and early or late realization times. Figure 3.8-1 shows the forecasted realization time in five-year blocks and the average index for the necessity of international co-operation for the topics in each of the time blocks.

Figure 3.8-1: Comparison of the international co-operation and the expected time of realization (Note: International Co-operation 1990- is omitted in this figure because the number of corresponding topics is negligible (Japan: 0; Germany: 3))



Japanese and German experts agree that the longer the time required for research and development, the higher the necessity for international co-operation. However, the German index is higher than the Japanese for topics whose realization time is earlier than 2010. The reason for this is that, as stated in 2.5, compared to Japanese experts, German experts assume that there is a stronger need for international co-operation in topics at the Widespread Use and Practical Use stages. In those phases, the realization times are predicted earlier than in the other two stages.

Whereas the German estimation on the necessity of international co-operation does not differ to a large extent between those topics which are predicted to be realized early and those which are forecasted for a later time, the Japanese experts estimation is much lower for topics with an early realization time than for those with a late realization time. This demonstrates, again that for Germany, international co-operation plays a large role in R&D projects in general.

3.9 Comparison of the Necessity for International Co-operation and the Present R&D Level

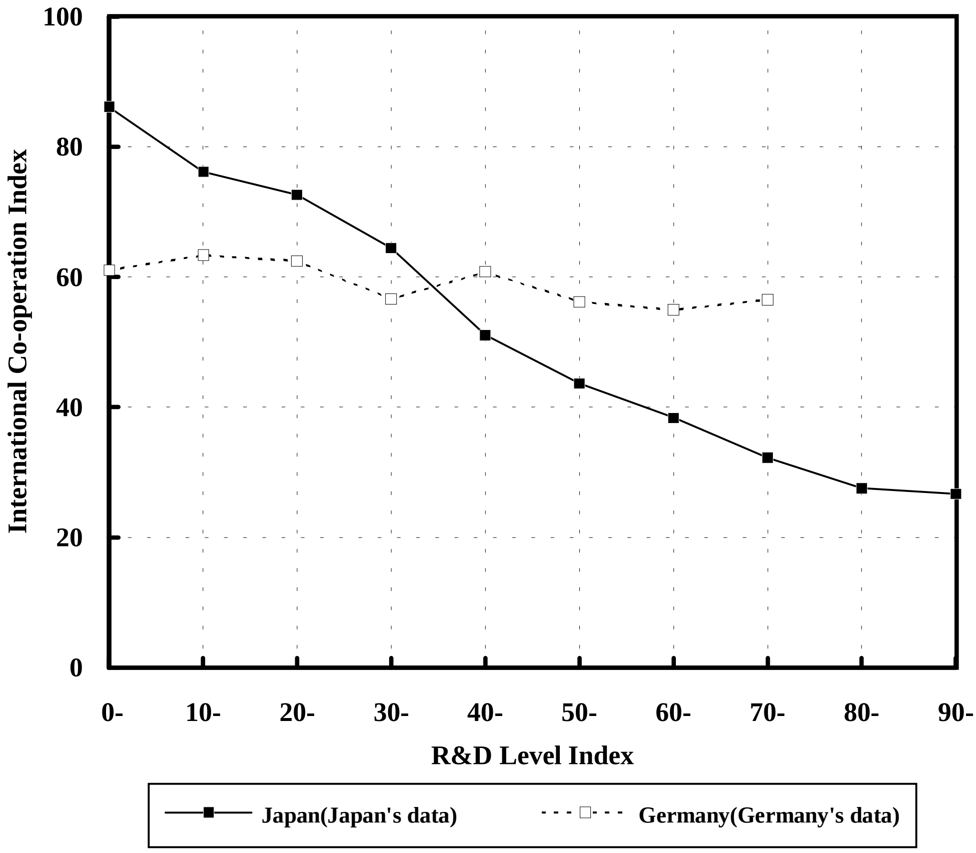
The German and the Japanese Delphi questionnaire asked for the R&D level only in the second round. Therefore, the index represents fewer opinions than for the other items of investigation. The Japanese questionnaire asked if Japan or other countries are advanced whereas the German questionnaire provided more possibilities to answer (USA, Japan, Germany or all other countries). For the calculation of the indices and further explanation see chapter 1.5.

Figure 3.9-1 shows the relationship between the R&D level and the necessity of international co-operation. The overall trend indicates that Japanese experts consider the necessity of international co-operation as high for topics, in which Japan's R&D level is low, and low for those topics in which the R&D level is high, whereas German experts consider the necessity of international co-operation to be roughly the same for all topics, regardless whether the R&D level is high or low.

This is thought to be attributed to the different way international co-operation is tackled, which itself stems from the differences in the geopolitical conditions of the two countries. This is analysed in detail in 3.11 in relation to the degree of importance. Neither of the two hypotheses that German researchers are more prepared to co-operate in deficit areas nor in areas of strength seem to be justified.

Some topics in which both countries' experts rate their own R&D level as high, and which German experts rate the importance of international co-operation as high and Japanese experts rate it as low are for example the *completion of marine traffic control systems which enable safe and efficient movement of all ships in congested areas such as Tokyo Bay/the German Bay* (J/G 14-38; Index of the necessity of international co-operation in Japan: 24, Germany: 85), the *establishment of comprehensive, wide-area water control and management technology for rivers, dams, and other water resources in the vicinity of major cities, enabling a more effective use of water resources* (J 12-3/ G 11-3; Index in Japan: 18; Germany: 72) or *widespread recycling of waste water such as sewage by means of sophisticated treatment so that it can be used for miscellaneous purposes (e.g., flush toilets) in*

Figure 3.9-1: *Relationship between R&D level and international co-operation (Japan and Germany) (As the number of topics is only six and under, International Co-operation (Germany) 80- and 90- is omitted in this figure)*



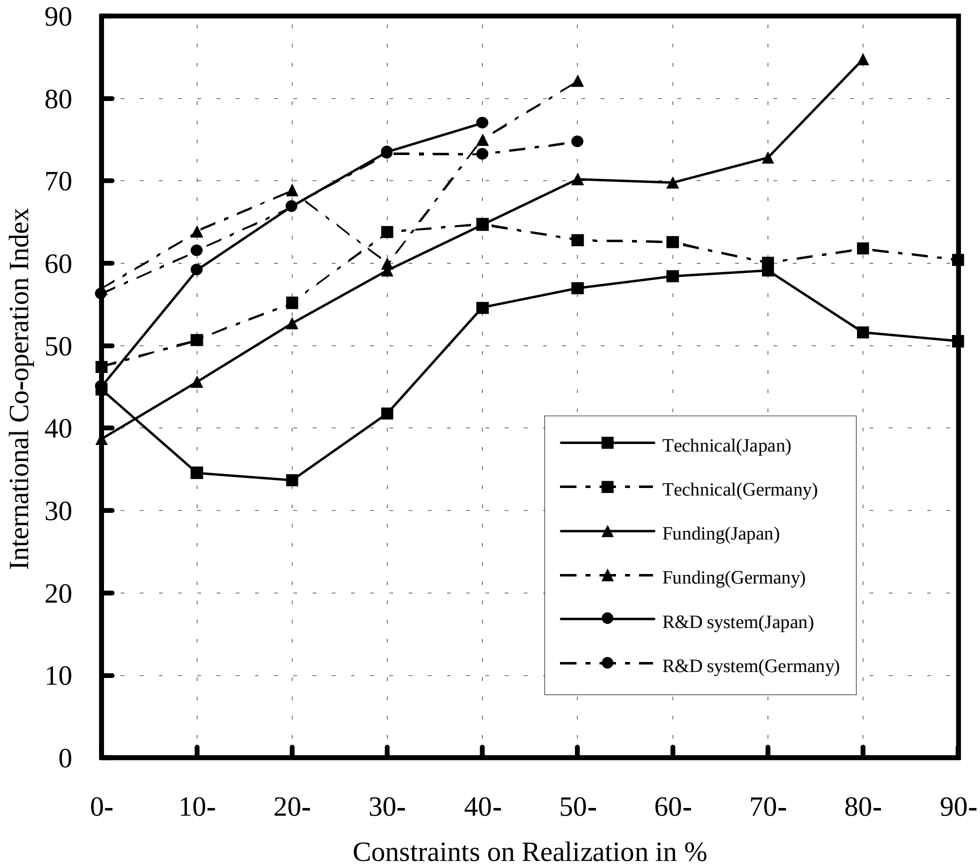
areas suffering from shortage of water (J 7-25/ G 6-25; Index in Japan: 21; Germany: 72). These topics are also discussed in chapter 4.4 and are estimated higher in Germany because of the different location of the country in the centre of Europe.

Topics, in which both countries' experts rate their own R&D level as low, and in which the Japanese experts rate the importance of international co-operation as relatively high but German experts rate it as low are the *development of technologies for digging the crusts of oceans to gather mantle materials* (J 6-61/ G 5-61; Index for the necessity of international co-operation in Japan: 88, Germany: 49), the *practical use of methods for analysing atomic fluctuations that allow slow changes to be traced such as fossilisation or organic corpses being gradually replaced by silica* (J 6-68/ G 5-68; Index in Japan: 57; Germany: 19), or the *possibility of complete sterilisation of food at a relatively low level of high pressure (approx. 3,000 bar) by combining physical and chemical methods to replace the conventional super high-pressure sterilisation, and practical use of the new sterilisation method which permits continuos processing as a general sterilisation technology* (J 10-22/ G 9-22; Index in Japan: 64, Germany: 33). These topics concern technologies which need international funding and international knowledge and, therefore, Japanese experts regard the international co-development as relatively important.

3.10 Correlation between Constraints and the Necessity of International Co-operation

Figure 3.10-1 shows that a relationship between the most frequent constraints and international co-operation has been identified. Experts from both countries suppose

Figure 3.10-1: *Japanese - German comparison of the necessity of international joint development versus constraints on realisation (In Germany's case there is only one topic in the "60-" and one in the "70-" for constraints in the R&D system, which is omitted therefore)*



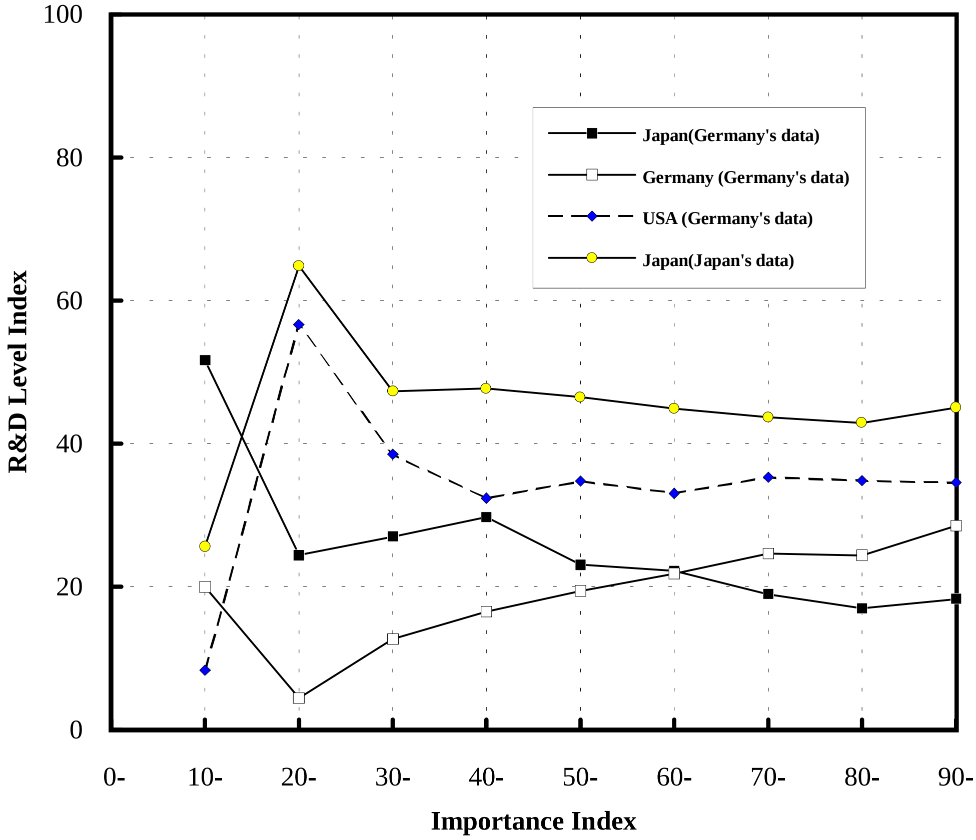
that international co-operation is important in topics with major technological constraints, though this tendency of increasing international co-operation with increasing technical constraints is not as strong among German experts as it is among Japanese experts. One reason might be that German experts generally do not expect technical constraints to be as important as their Japanese colleagues do.

Similarly, Japanese and German experts assume that international co-operation is vital in topics with major funding constraints, and also in topics with constraints in the R&D system. Thus, it can be observed that experts from both countries share the view that funding and structural difficulties within technologies can generally be offset by international co-operation.

3.11 Correlation of the R&D Level and the Importance of the Topics

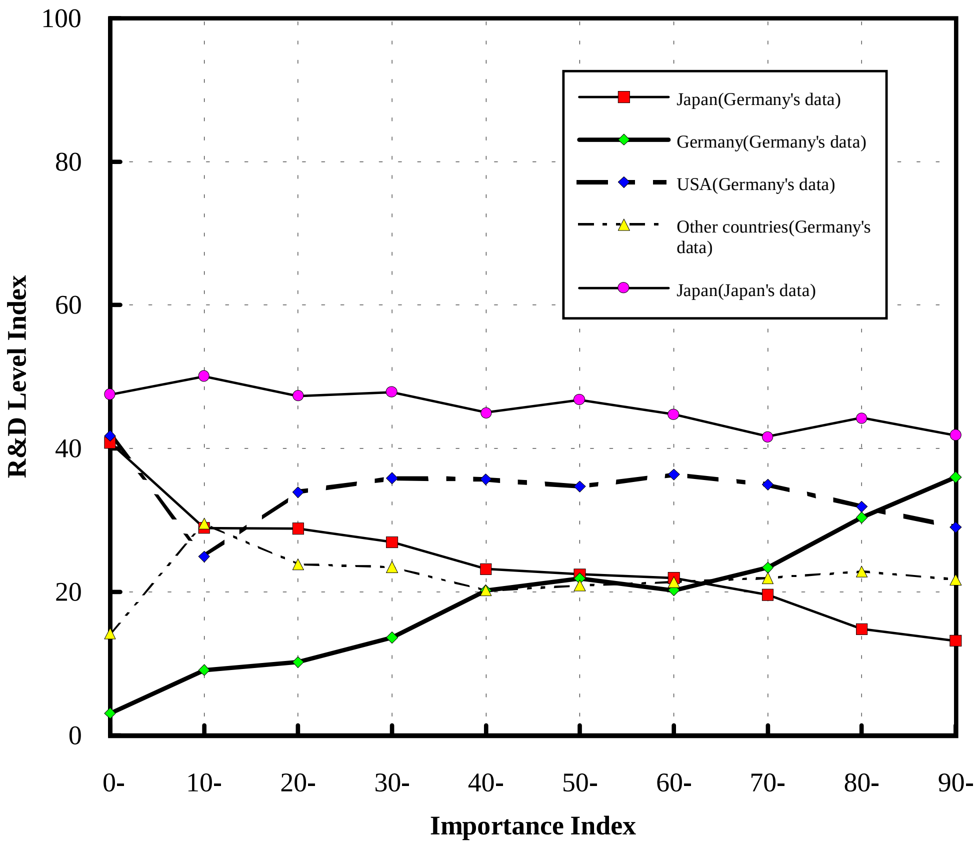
The relationship between the importance and the R&D level of the topics was calculated by using the Japanese experts' assessment of importance divided into blocks of ten points. This relationship is shown in Figure 3.11-1.

Figure 3.11-1: Relationship between the importance and the R&D level (based on the Japanese experts' assessment of importance. R&D level 0- is omitted in this figure because the number of corresponding topics is zero)



The Japanese experts' rating of the Japanese R&D level tends to be slightly lower for those topics which are important to the Japanese, and the assessment of Japan's R&D level by German experts follows a similar trend which is more expressed. The difference in absolute values (percentages) here, is due to the different items (more countries in the German survey) and may be neglected for a comparison. Figure 3.11-2 shows the relationship between importance and the R&D level based on the German experts' assessment of the importance of topics.

Figure 3.11-2: Relationship between the importance and the R&D level (based on the German experts' assessment of importance)



In this case, the perception of both groups of experts is that Japan's level of R&D is quite low in topics with an attributed high importance in Germany. This trend is much stronger than that shown in Figure 3.11-1. In Germany's case, the perception is quite the opposite: the higher the importance of the topic, the higher the level of German R&D. As for the United States, the importance - R&D level relationship is fairly uniform and no special trend can be seen.

Two points of difference between the views of Japanese experts and German experts can be identified from Figures 3.11-1 and 3.11-2. The first is that the higher the importance of a topic is evaluated in Germany, the higher German experts rate their R&D level, however, such a clear relationship cannot be seen in the case of Japanese experts. This is quite the opposite of the difference in the relationship between the necessity of international co-operation and the level of R&D mentioned in 3.9 (In the German survey the perceived necessity of international co-operation is uniform, regardless the R&D level, while in the Japanese survey, the lower the level of R&D the higher the perceived necessity of international co-operation). That is to say, the relationship between importance, necessity of international co-operation, and R&D level is in:

- Japan: The higher the importance of the topic, the higher the necessity of international co-operation, however, the R&D level is generally uniform.
- Germany: the higher the importance of the topic, the higher the R&D level, however, the necessity of international co-operation is generally uniform.

Here, we can see the difference between Japan and Germany in the basic concept of R&D arising from geographical, historical and geopolitical factors. Japan, an island nation which does not share a land border with any other country and which does not have any neighbouring countries with a comparable level of science and technology, has to proceed with its own wide-ranging R&D without specialising to any great extent from an importance, or urgency point of view. Under this concept, areas in which Japan's R&D alone is not sufficient, are supplemented with overseas co-operation.

In contrast, Germany, which is located amid the various countries of Europe and a member of the European Union, regularly co-operates with neighbouring countries in numerous technologies, and it is within this intertwining relationship that Germany actively pursues research and development in technologies upon which it places importance herself. And this is thought to have led to the present state in which the German R&D level is high in technologies that are considered important, as can be seen in Figure 3.11-2: A result of division of R&D labour in Europe.

The second is that, as can be seen in Figure 3.11-2, German experts' assessment of Japan's R&D level in topics ranging from a high importance to a low importance is almost directly inverse to their assessment of the corresponding German R&D level. The following examples are typical for topics in which Germany's R&D level is higher than Japan's, and the topic importance is assessed by German experts as higher than the average of all topics: *widespread use of recycling systems for fabrics and apparel, food packing materials, and other home materials* (J/G 16-14; Index in Japan: 0, Germany: 100), the *development of comprehensive control systems based on the elucidation of the mechanisms of control of* *pathogenic bacteria and harmful insects in natural forest ecosystems and on the establishment of techniques to prevent the appearance of major pests* (J 10-45/ G 9-45; Index in Japan: 0, Germany: 88); or *quantitative determination of the influences of acid rain on the water system, allowing corrective measures to be formulated* (J 7-38/, G 6-38; Index in Japan: 0, Germany: 80) (Note: the indices in the topics are the indices of the comparison of the R&D level in Japan and Germany resulting from the *German* experts estimation).

All of the top 20 topics, in which the gap between Japanese and German R&D level is largest, are connected with the environment, including environmental preservation, waste recycling, and waste treatment and disposal. This might be due to a different consciousness about such themes in Germany which results from the "green movement" and other factors. But, as a matter of fact, if a clean environment is considered as an economic and social resource, then, this is a greater lack of this specific resource in the centre of the European continent with its dense population. Under island conditions like in Japan and in less densely populated regions like Russia or America, environmental resources are not as scarce. Therefore, the respective R&D priorities and R&D levels appear to be rationale.

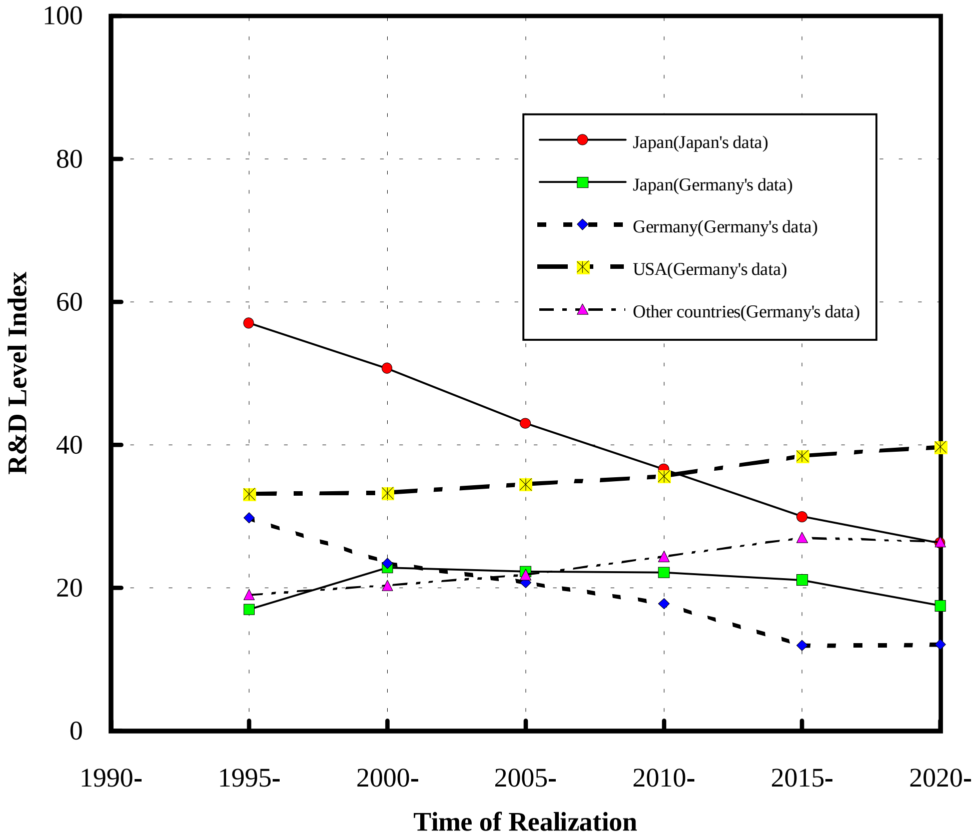
Conversely, the following are some examples of topics in which Japan's R&D level is assumed to be higher than Germany's and the topic importance is assessed by German experts as higher than the average of all topics: *Practical use of semiconductor optical detecting devices with more than one million pixels capable of detecting one photon in a visible light area* (J 5-69/ G 4-23; Index in Japan: 100, Germany: 0), the *widespread use of colour video display panels with a resolution of at least 2,000x2,000 pixels* (J/G 2-26; Index in Japan: 84, Germany: 0); or the *practical use of flat displays capable of displaying A3-size information in near-actual size at high quality, leading to dramatically improved office automation working* (J 13-35/ G 12-35; Index in Japan: 78, Germany: 0). Of the top 20 topics in which the gap between Japanese and German R&D level is largest, 16 are connected with electronics, including electronic devices and flat displays. This is equivalent to the priority setting found in chapter 4.2.

The following are examples of topics in which Japan's R&D level is higher than Germany's and the topic importance is assessed by German experts as lower than the average of all topics. These are the *practical use of selective fishing methods* *for catching desired size and species of fish and of inductive fishing for catching desirable water area through the development of technologies that are able to control the behaviour of a shoal of fish* (J 10-56/ G 9-56; Index in Japan: 100, Germany: 0); the *progress in projects for developing and utilising great underground factories* (J 11-11/ G 10-11; Index in Japan: 100, Germany: 0), the *commercialisation of electric power tankers capable of storing and transporting electricity in its original state* (J 11-23/ G 10-23; Index in Japan: 100, Germany: 0), or the *development of energy-saving airconditioning systems which enable individuals and consumers to make low cost products designed to their own tastes in function, shape and colour* (J 11-60/ G 10-60; Index in Japan: 100, Germany: 0). Of the above mentioned top five topics in which the gap between Japanese and German R&D level is greatest, three are in the Production areas. By explaining these large gaps it has to be kept in mind that on the German side, only few experts answered the criteria R&D level and therefore, some of the answers may not be representative. But nevertheless, those German experts who did not specify the R&D levels definitely stated that they had no knowledge by which to decide which country is more advanced. Probably, they are familiar with R&D projects in Japan. This would underline the unsophisticated knowledge base in Germany in those fields.

3.12 Time of Realization and R&D Level

Figure 3.12-1 shows the relationship between the forecasted realization time for the various topics and the R&D level.

Figure 3.12-1: *Relation between the forecasted year and the current R&D level (Japan and Germany) (As the number of corresponding topics is low (Japan: 0, Germany: 3), R&D level 1990- is omitted in this figure)*



Japanese experts have assessed that Japan's R&D level is remarkably low in topics that will take a long time to be realized. That means - vice versa - if Japanese experts estimate the Japanese R&D level to be the most advanced, their prediction of the realization time is earlier than for those projects in which their R&D level is

not assumed to be so high. In these cases, the efforts to achieve the realization have to be higher.

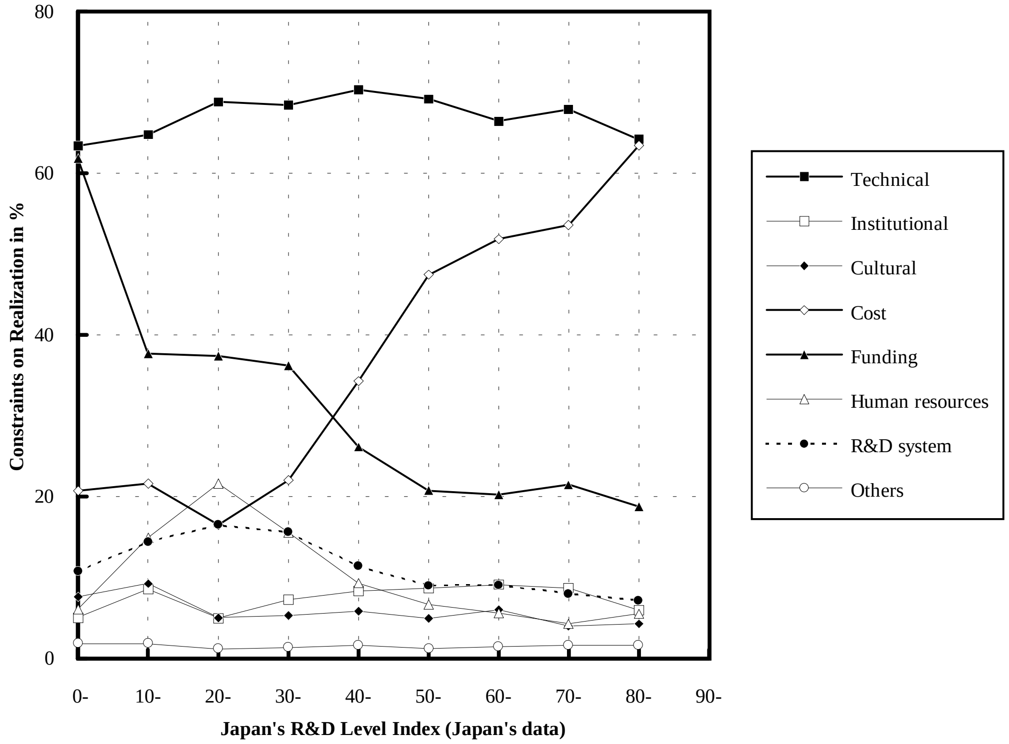
German experts tend to have a somewhat different view regarding the long-term topics, while recognising that the R&D level in the United States and other countries is higher. For those topics, in which R&D in the USA is assumed to be the most advanced in the world, there are early as well as late realizations expected. German experts, thus, assume that the US level remains high. For those topics, in which Japan is supposed to be the technical leader, there are also early and late realizations expected by the German experts. Contrary to the Japanese estimation, they do not consider the Japanese being advanced in so many fields as the Japanese experts do themselves.

Interestingly, concerning their own R&D level, Germans judge similar to the Japanese: They are convinced that their national R&D system is stronger in short-term innovation projects. The results of these surveys clearly show that both the Japanese experts and the German experts are far from being optimistic about the progress of long-term research topics in which the R&D level of their respective countries is not the most advanced.

3.13 Correlation between the R&D Level and the Various Constraints on the Realization

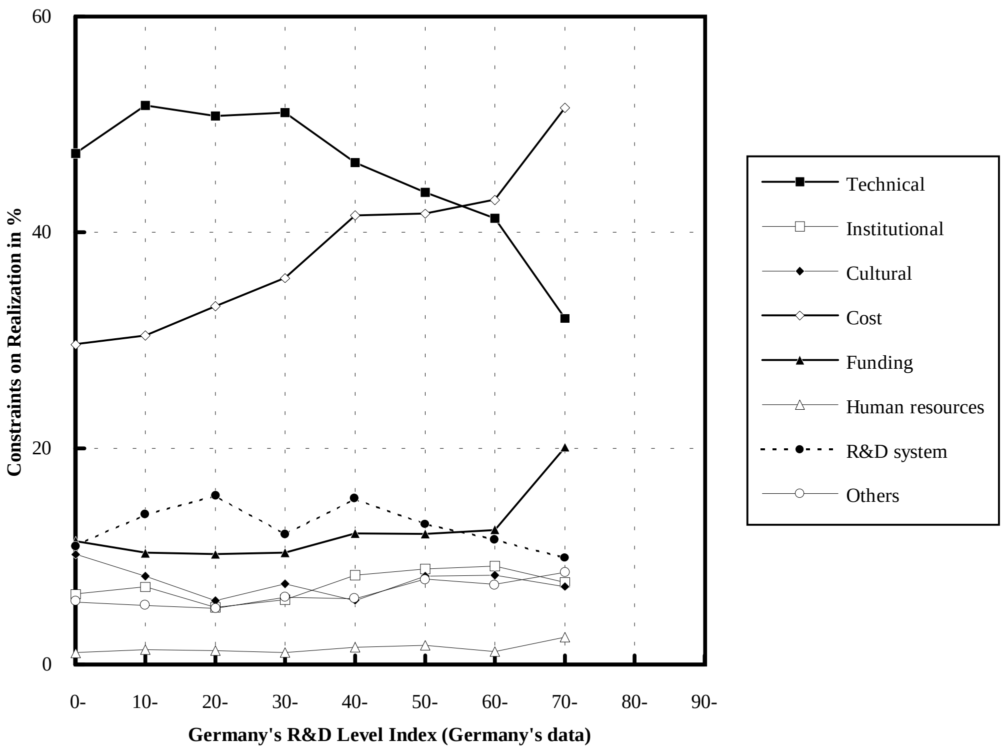
The relationship between R&D level and the various constraints is shown in Figure 3.13-1 for Japan and 3.13-2 for Germany.

Figure 3.13-1: Relationship between Japan's R&D level and the various constraints (Constraints 90- are omitted in this figure because the number of corresponding topics is only four)



Constraints that stand out in the two figures are technical constraints, cost constraints, and funding constraints. As for technical constraints the Japanese view is generally uniform regardless of the R&D level of the topic, whereas German experts estimate that technology is less of a constraint in those topics where their

Figure 3.13-2: *Relationship between Germany's R&D level and the various constraints (Constraints 80- and 90- are omitted in this figure because the number of corresponding topics is six and below)*



R&D level is high. This difference can be attributed to the gap between Japanese and German experts in their perceptions related to the R&D level. That is, there is a general agreement between the two groups of experts in importance and technical constraints as will be mentioned in chapter 3.14. However, as for importance and the R&D level, the German R&D level is higher in topics with a high degree of importance as well, while the Japanese R&D level remains fairly uniform, as mentioned in chapter 3.11. This, therefore corresponds to the trend that few German experts pointed to technical constraints as an issue in topics with a high R&D level.

As for cost constraints, both countries show a similar trend; namely, the higher the R&D level of the topic, the higher also the number of experts who indicated costs as a constraint. The increase is, however, much sharper in Japan's case. As stated in chapter 2.6, the R&D level is highest for the technological stage of Widespread Use and this explains why both countries rated cost constraints as the highest in the Widespread Use innovation stage as mentioned in 2.7.4.

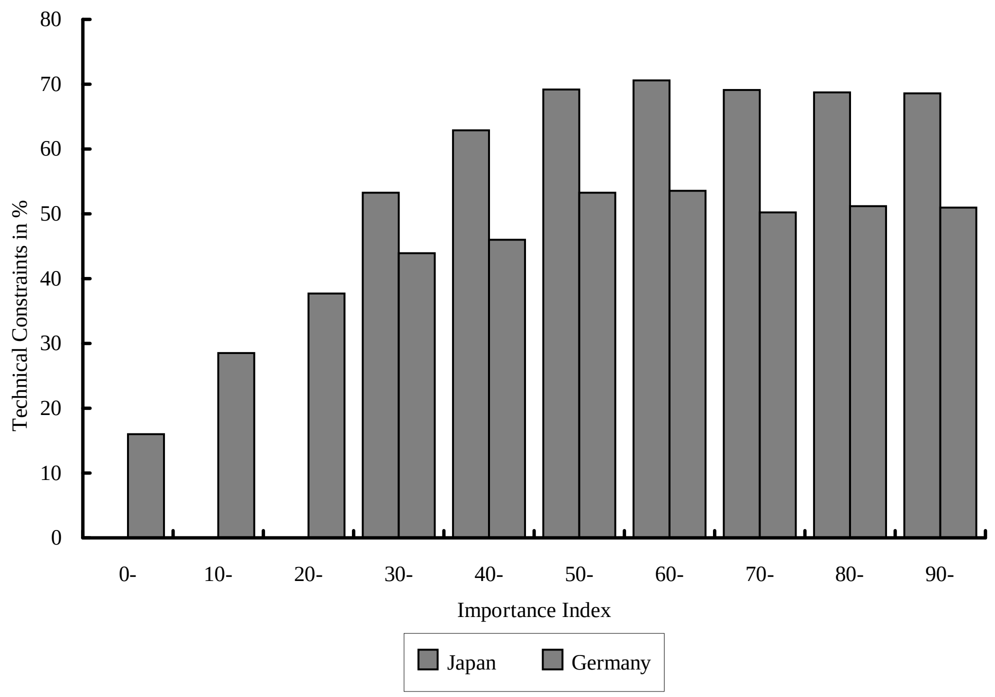
Regarding funding constraints, one can observe that as the level of R&D in the topic increases, the funding constraints are generally lower in Japan's case, but remains fairly constant in the German estimation. In Japan's case, this difference can be put down to the low level of investment by the government sector, which shoulders the main funding burden in the Elucidation and Development stages, compared to the amount of the private sector, which is the main source of funds for the Practical Use and Widespread Use stages, the two phases, in which the R&D level is assumed to be highest.

3.14 Comparison of the Importance and the Various Constraints on the Realization

In this section, a comparative analysis of both countries is conducted on the relationship between topic importance and the various constraints. However, the number of topics in which Japan's importance index is less then 30 is extremely small (seven topics), so that these topics have been excluded from this analysis.

3.14.1 Technical Constraints

Figure 3.14-1: Japanese - German comparison of technical constraints versus importance (The number of topics in which the importance index in the Japanese survey is less than 30 is extremely small, so that these topics have been excluded from this figure)



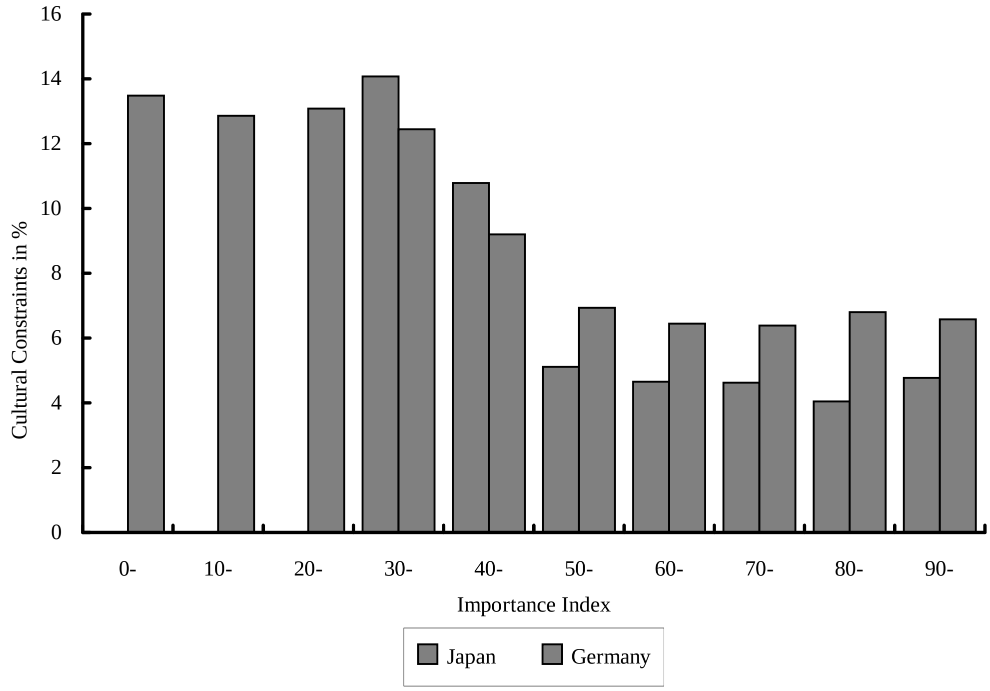
Technical constraint indices for both countries follow a similar trend; the index rises in proportion to the rise in the importance index (Figure 3.14-1). This may be due to the high proportion of topics with a high importance index which have to do with environmental or cancer research - or in the case of Japan - with computer technology. The related projects are obviously estimated to have their limitations in the technical realization. But for deeper analysis, further investigation on the individual topics' technical constraints are necessary.

3.14.2 Cultural Constraints

German experts indicated cultural constraints more than their Japanese counterparts in topics with an importance rating of 50 or more (Figure 3.14-2).

Examples of topics which are considered as important by both, Japanese and German experts, and for which the German cultural constraint index is higher than the Japanese index are e.g., the *widespread use of personal nutritional indices that take individual differences, age, and regional idiosyncrasies into account through the scientific elucidation of the interrelationships between nutrition and metabolism, exercise, physical strength, etc.* (J/G 16-1; Cultural constraint index in Japan: 31, Germany: 79), the *development of systems for determining combinations of nutritive elements necessary for recovering from morbid states or for maintaining health* (J/G 15-85; Japan: 1, Germany: 44), the *practical use of systems for monitoring family health and providing information for an appropriate diagnosis at home in event of accident or disease* (J/G 15-98; Japan: 2, Germany: 44), or the *predominance of preventive medicine in medical science* (J/G 15-24; Japan: 15, Germany: 58).

Figure 3.14-2: Japanese - German comparison of cultural constraints versus importance (The number of topics in which the importance index in the Japanese survey is less than 30 is extremely small, so that these topics have been excluded from this figure)



Those topics, in which the Japanese cultural constraint index is higher than the German index are i.e., the *widespread use of technologies for preserving historical environments including historical neighbourhoods because of growing interests in preserving and restoring historical structures* (J 12-6/ G 11-6; Japan: 52, Germany: 4), the *perfection of systems to lengthen organ preservation, enabling world-wide supply of some kinds of organs for transplantation* (J/G 15-88; Japan: 52, Germany: 8), the *construction of cities that present diverse landscapes including roads and bridges thanks to the advancement of landscape design technologies* (J 12-29/ G 11-29; Japan: 60, Germany: 20), and *dramatically reduced foetal death and births of premature babies owing to advanced systems for acquiring and controlling information on foetuses* (J/G 15-21; Japan: 35, Germany: 16).

The first examples are mainly connected with Medical Care and Health, while the topics with a higher estimation in the Japanese Delphi survey are those on which public concern in Japan is currently focused, namely technology to preserve important sights and scenery within the technological field of Urbanization and

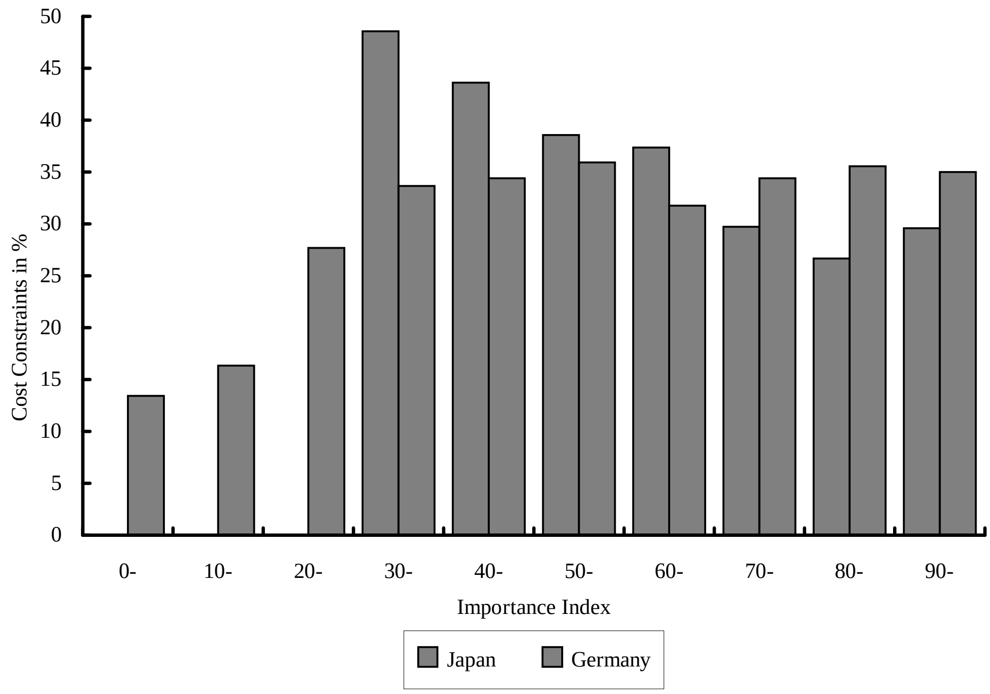
Construction, and the organ transplantation and foetal information from Medical Care and Health. The reason for the German index is thought to be that Germany has already passed through the stage of social debate about these topics. As can be seen in the first examples, the fact that cultural issues such as the spread of medical care technology to the home and into people's individual sphere which effect their individual lives are now at the forefront of German social consciousness and can be seen as a sign of things to come for Japanese medical care and health.

3.14.3 Constraints in Costs

Whereas Japan's cost constraint index generally decreases as the importance of the topics increases, the German cost constraint index remains fairly constant, regardless of the topics' importance (if it is above 30). As can be seen in Figure 3.14-3, the cost constraint index for Japan and Germany inverses at the point where the importance index is 70.

The reason for this is that the German cost constraint index is much higher than Japan's in topics at the Elucidation stage. The importance of these topics is generally high, whereas the Japanese cost constraint index is greater than Germany's in topics at the Widespread Use stage, for which importance is regarded as somewhat lower (refer to Figure 2.7-9). Examples for basic research topics in which the Germans assume to face higher costs are the *elucidation of the onsetting mechanism of Alzheimer's disease* (J/G 15-5; Costs constraint index in Japan: 2, Germany: 61), the *practical use of diagnosing methods for determining the level and spread of ateriosclerosis focuses by non-invasive methods* (J/G 15-35; Japan: 11, Germany: 63), or the *elucidation of mechanism of canceration for virtually all types of malignant neoplasms* (J/G 15-4; Japan: 6, Germany: 54).

Figure 3.14-3: *Japanese - German comparison of costs as a constraint (The number of topics in which the importance index in the Japanese survey is less than 30 is extremely small, so that these topics have been excluded from this figure)*



Examples for topics for which the cost constraint index is estimated higher by the Japanese experts are the *widespread use of personalised indoor environments where air-conditioning, light, sound, and other environments are individually created in addition to private rooms* (J 12-36/ G 11-36; Japan: 88, Germany: 25), the *widespread use of factory entertainment where operators and visitors can both enjoy. (Systems designed for publicity and entertainment of people as a part of enhance expressing of identities of companies and research organisations)* (J 11-62/ G 10-62; Japan: 56, Germany: 13), or the *widespread use of equipment capable of adjusting the freshness or ripeness of perishable foods at home* (J/G 16-48; Japan: 72, Germany: 31). The overall impression is that from the Japanese point of view, costs are a major problem in innovations which deal with daily life and leisure. Here, many German experts expect decisive obstacles against realization more from the side of cultural or societal reservations than from costs.

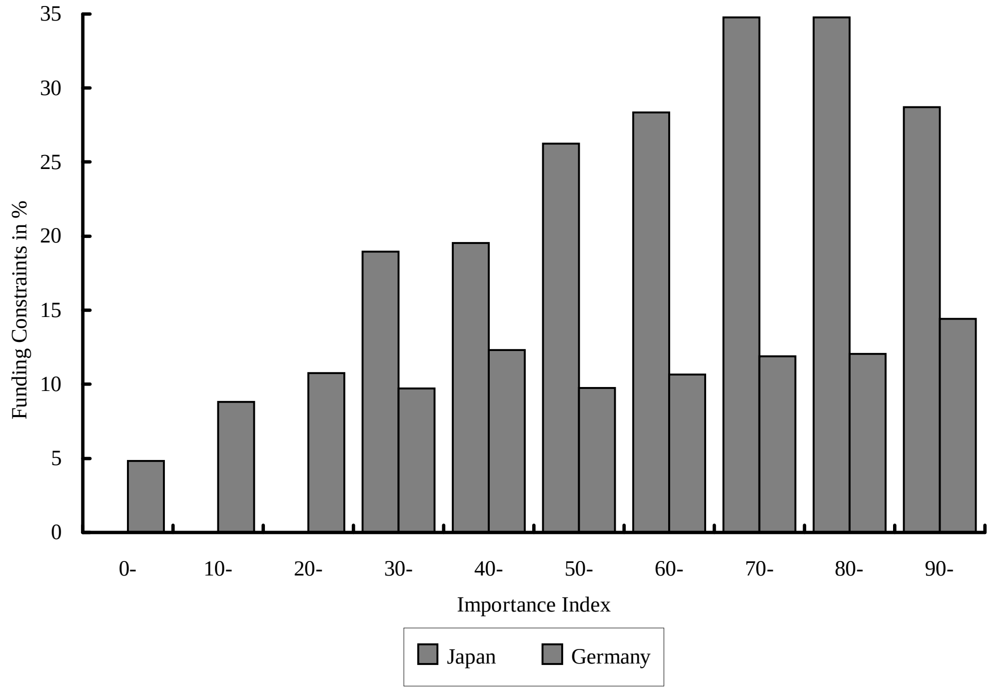
3.14.4 Constraints in Funding

The Japanese index for constraints in funding tends to increase as the topic importance increases, while the German index remains fairly constant, regardless of the importance of the topic. In most blocks, the Japanese funding constraint index is higher than the German index (Figure 3.14-4).

The following are examples of topics with an importance index for Japan of 70 or more and in which there is a considerable gap between Japanese and German experts' views about funding constraints:
Practical use of microwave radiometers to be mounted on satellites, which are designed for measuring water, soil moisture, salt deposit concentration, and ice/snow distribution on land over the entire earth with space resolution of 1 km or less (J 4-21/ G 13-21; Funding constraint index in Japan: 74, Germany: 6).
Practical use of a robot equipped with sophisticated artificial intelligence and flexible arms for performing difficult tasks in space (J 4-25/ G 13-25; Japan: 76, Germany: 11).
Nation-wide installation of bore-hole observation equipment integrating various types of gauges (e.g. seismometers, tiltmeters, and strain-gauges) for use in earthquake forecasting (J 6-54/ G 5-54; Japan: 71, Germany: 6).
Realization of forecasting volcanic eruption with certainty 2 to 3 days in advance (J 6-76/ G 5-76; Japan: 60, Germany: 0).
Elucidation of individual ageing mechanism, being applied for prevention of ageing (J/G 15-106; Japan: 60, Germany: 0).
Development of totally implantable artificial hearts powered by high order sources (J/G 15-74; Japan: 66, Germany: 10).

The reason for such a large gap in the technological area of Space is that Germany is proceeding with space research and development as a member of the ESA, so that funding is not regarded as an "extra" problem, whereas most of Japan's space research and development is carried out independently. In the area of Medical Care and Health, funding is not regarded as a problem because there is a sufficient

Figure 3.14-4: *Japanese - German comparison of constraints in funding versus importance (The number of topics in which the importance index in the Japanese survey is less than 30 is extremely small, so that these topics have been excluded from this figure)*



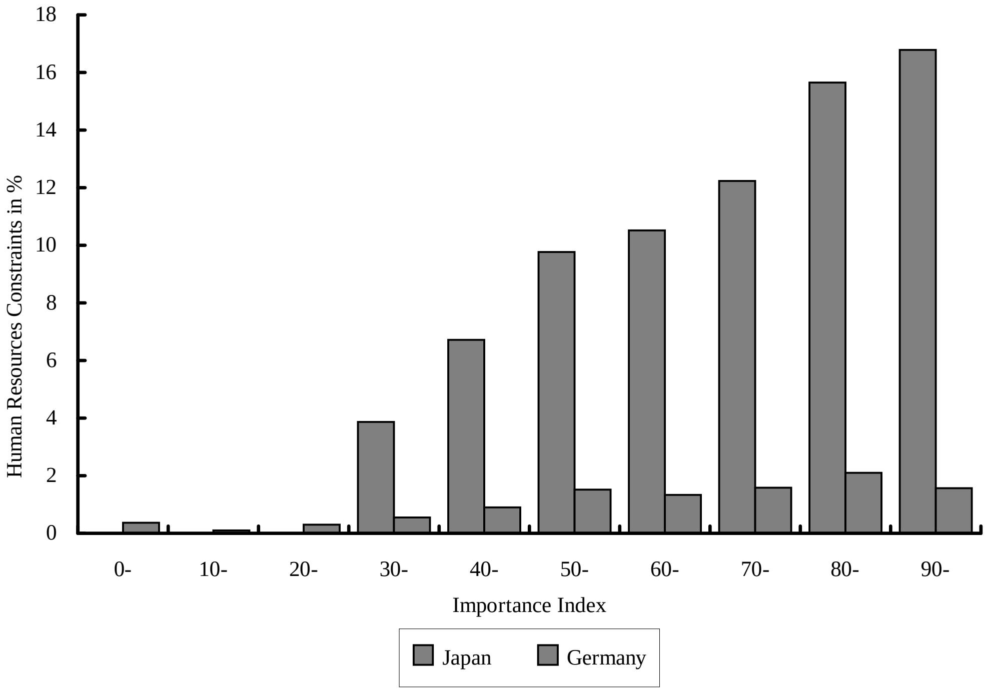
number of well-equipped institutions or hospitals available where such research could be done but the costs are the limiting factor. The recruitment of qualified personnel is known as a serious problem in Japan. Judging from Figure 3.14-5, this problem is more serious in the more important future tasks than elsewhere which makes the issue even more dramatic.

3.14.5 Constraints in Fostering or Securing Human Resources

The Japanese index for constraints in fostering or securing human resources increases almost rectilinearly as the assessed importance of the topic increases. On

the other hand, very few German experts pointed to human resources constraints as a problem (Figure 3.14-5).

Figure 3.14-5: *Japanese - German comparison of constraints in fostering or securing human resources (The number of topics in which the importance index in the Japanese survey is less than 30 is extremely small, so that these topics have been excluded from this figure)*



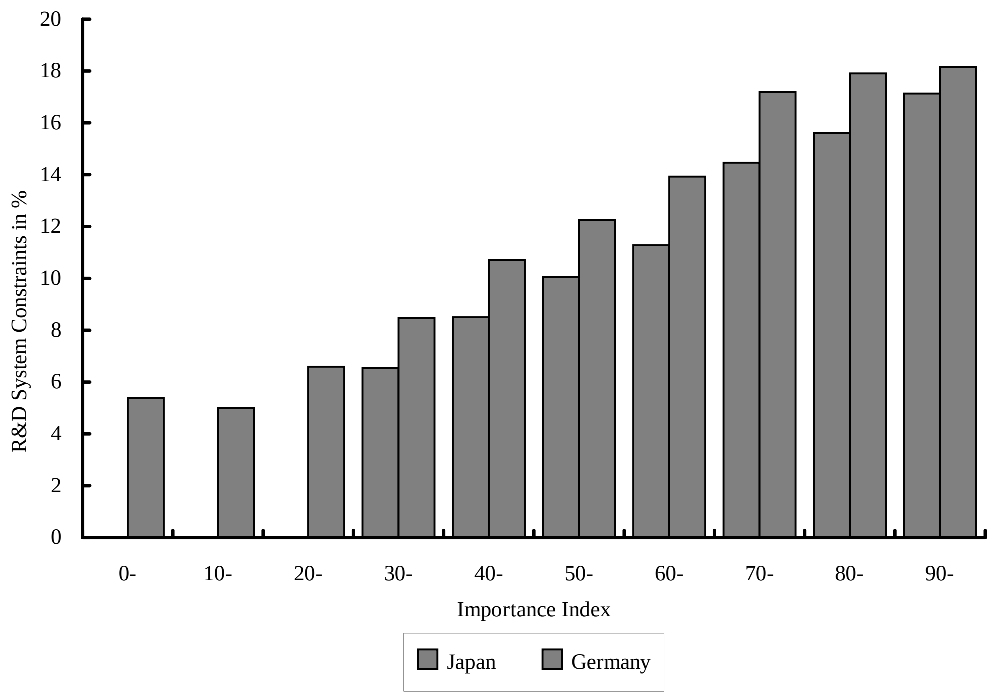
Examples of topics from the field of Life Sciences with an importance index for Japan of 70 or more in which there is a considerable gap between Japanese and German experts' views about human resources as a constraint are the *elucidation of the morphogenic and developmental processes of the brain at the molecular level* (J/G 3-10; Index in Japan: 54, Germany: 0), the *elucidation of relationships between the higher-order structures and functions of the nuclei of eukaryotic cells* (J/G 3-1; Japan: 51, Germany: 0), and the *elucidation of the mechanisms of replication and (cell) division of eukaryotic cells* (J/G 3-24; Japan: 51, Germany: 2).

As already discussed in 2.7.6, human resources are a minor constraint of realization in Germany.

3.14.6 Constraints in the R&D System

The relationship between topic importance and constraints in the R&D system for both Japan and Germany follows a similar trend: the R&D system constraint index increases as the assessed importance of the topic increases. In each block, the German constraint index is higher than the Japanese index (Figure 3.14-6).

Figure 3.14-6: *Japanese - German comparison of the R&D system as a constraint versus importance (The number of topics in which the importance index in the Japanese survey is less than 30 is extremely small, so that these topics have been excluded from this figure)*



Examples of topics with an importance index for both countries of 70 or more and also high R&D system constraint indices are e.g., the *elucidation of precise mechanisms of the emission and extinction of carbon dioxide in the atmosphere* (J 9-6/ G 8-6; Japan: 39, Germany: 35), the *possibility of accurate forecast of the sea level rise caused by global warming* (J 9-9/ G 8-9; Japan: 32, Germany: 48), or the *determination of impacts of global warming on the whole world's agricultural production* (J 9-11/ G 8-11; Japan: 42, Germany: 43).

As discussed in chapter 2.7.7, major problems in the R&D system concerning important research issues could be detected for both, Japan and Germany. For further explanations, see also chapter 4.6. This well-known situation seems to effect the solutions of important innovation projects more than the others. This underlines the significance of technology foresight itself. Foresight activities should help to re-orient the priorities of the respective national R&D systems to the more important tasks of our societies.

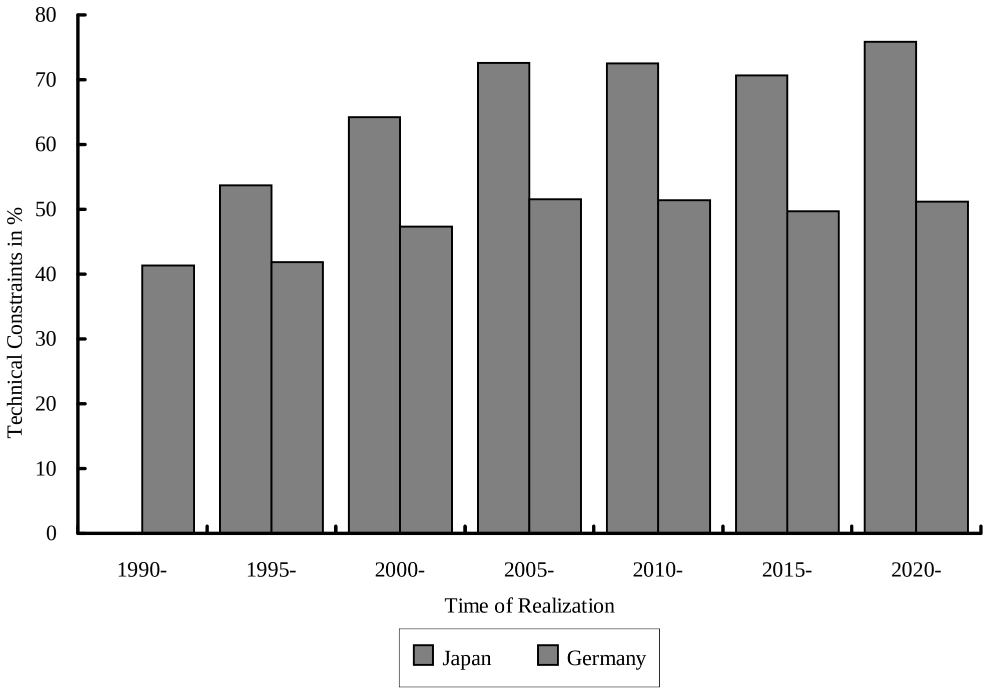
3.15 Time of Realization in Comparison with the Constraints on Realization

In this section, a comparative analysis of both countries was conducted on the relationship between the realization time and various constraints. Of the various constraints, here technical, funding, human resources, and R&D system constraints are discussed, all of which display distinctive features.

3.15.1 Technical Constraints

German and Japanese experts' views on technical constraints generally follow a

Figure 3.15-1: Japanese - German comparison of technical constraints versus time (In Japan's case, there are no topics with a forecasted realization time in the block of "1990-1994")

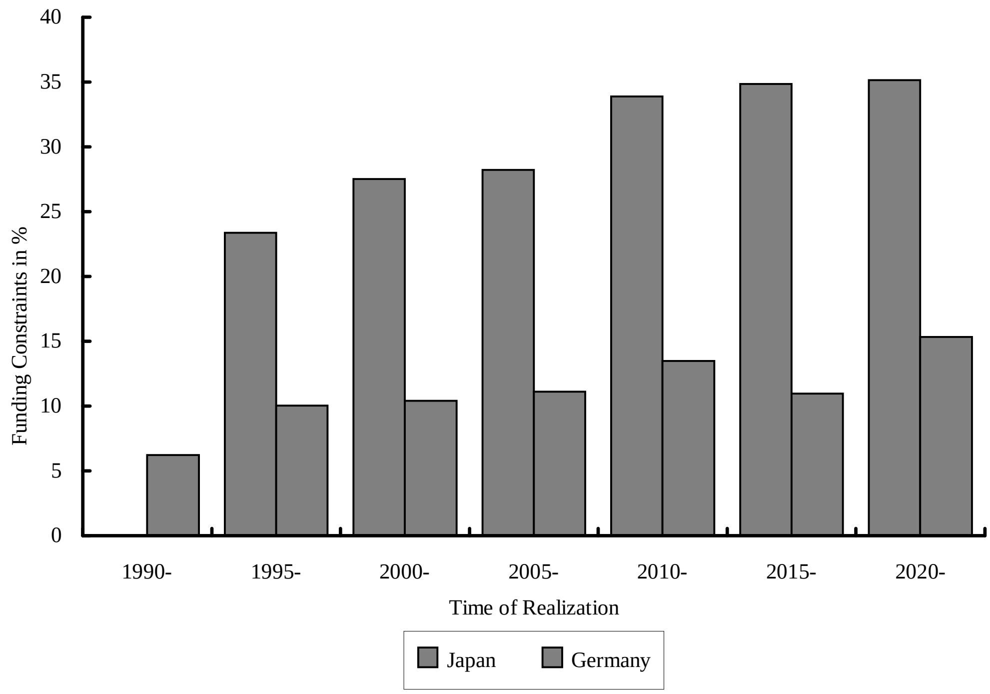


similar trend: the constraint indices are fairly uniform for both countries apart from topics with an early realization time, in which the index is somewhat lower (see Figure 3.15-1). It was expected that the higher the technical constraint index, the later the time of realization should be expected but no such simple conclusion can be drawn. Therefore, the reason for the later realizations have to be looked for in the character of the individual topic and not in the technical problem itself.

3.15.2 Constraints in Funding

German and Japanese experts share the view that funding constraints increase slightly as the forecasted realization time becomes longer. Moreover, in all time

Figure 3.15-2: Japanese - German comparison of constraints in funding versus time of realization (In Japan's case there are no topics with a forecasted realization time in the block of "1990-1994")



blocks Japan's funding constraint indices are more than twice as high as the corresponding German indices. Japanese experts therefore judge in a way that the longer the lead-time for the technology, the more funding is required (see Figure 3.15-2).

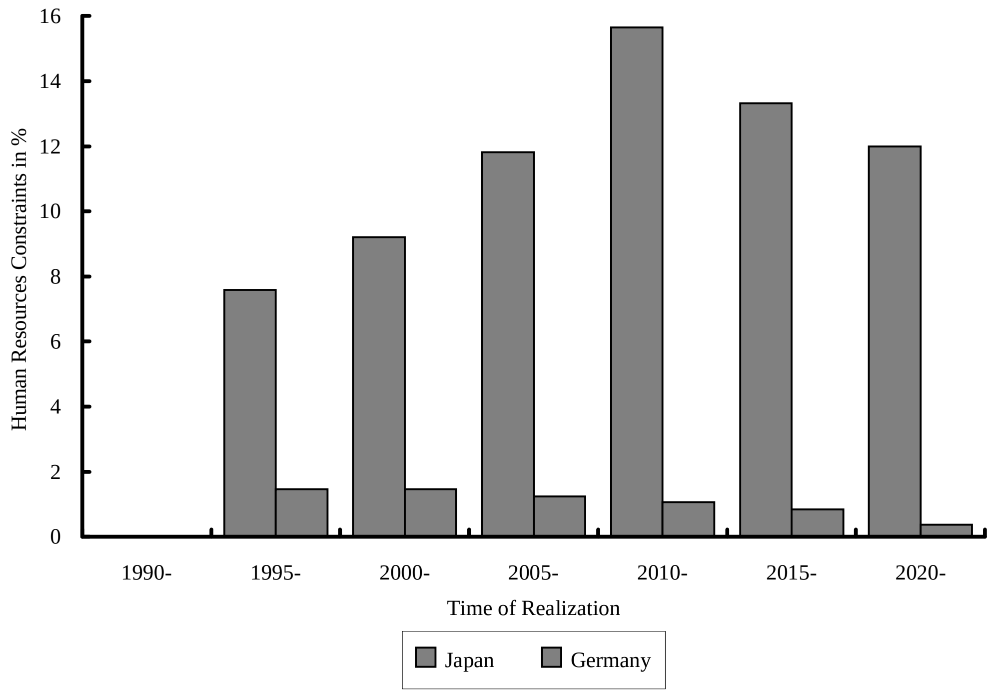
Topics in which experts from both countries have forecasted a somewhat later realization time and in which there is a considerable gap between the two groups of experts in their funding perceptions can be seen in the Medical Care and Health area, e.g., the *elucidation of individual aging mechanism, being applied for prevention of aging* (J/G 15-106; Funding constraint index in Japan: 60, Germany: 0), the *possibility of a complete cure of obstructive pulmonary diseases using medicines* (J/G 15-76; Japan: 54, Germany: 0), or the *elucidation of the mechanism of disease onset for virtually all genetic diseases* (J/G 15-8; Japan: 65, Germany: 13). This different funding assessment does not reflect a totally different perception as might be assumed by the zero or low estimation on the German side - but the German experts regarded cost constraints in these cases as the more important constraint on realization. As already explained in chapter 2.7, German experts often chose the cost- or the R&D level constraint instead of funding, like in these examples, and it has to be kept in mind that only two constraints could be chosen.

3.15.3 Constraints in Fostering or Securing Human Resources

Peaking in the 2010 time block, the Japanese indices for constraints in fostering or securing human resources are much higher than the corresponding German indices, which are quite low in all time blocks (see Figure 3.15-3).

Topics in which there is a considerable gap between the Japanese and German experts in their estimation of human resources can be seen mainly in the Life Sciences area. Examples are the *elucidation of the relationship between molecular*

Figure 3.15-3: *Japanese - German comparison of constraints in fostering or securing human resources versus time of realization (In Japan's case there are no topics with a forecasted realization time in the block of "1990-1994")*

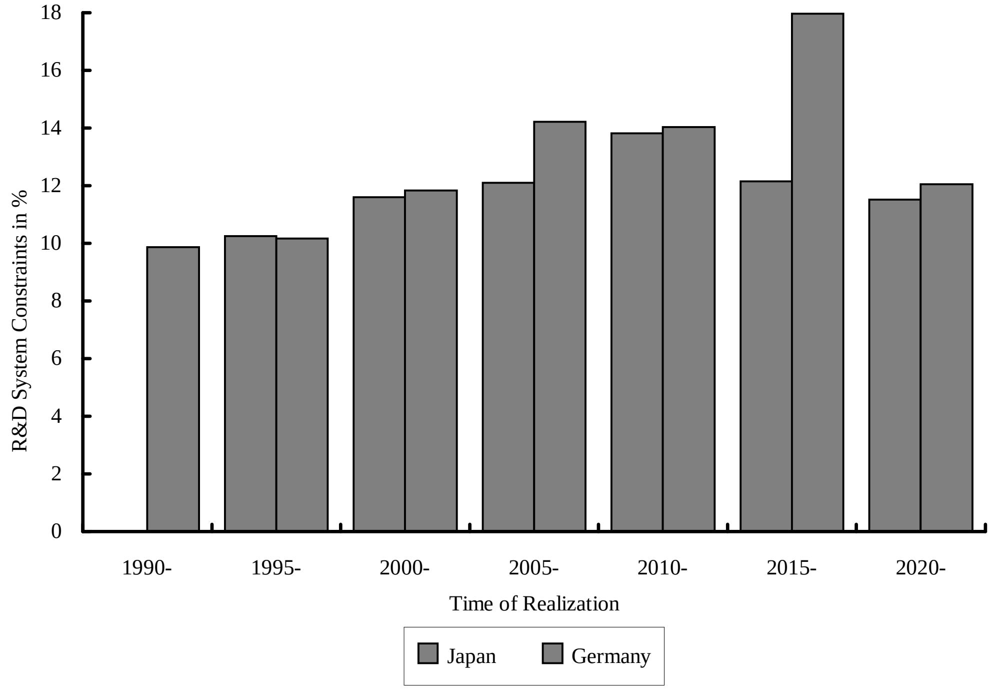


and morphogenetic evolution (J/G 3-91; Human resources constraint index in Japan: 54, Germany: 0), the *elucidation of the morphogenic and developmental processes of the brain on the molecular level* (J/G 3-10; Japan: 55, Germany: 3), and the *elucidation of the molecular basis of animals' actions such as contacting, sexual behaviours, and migrations* (J/G 3-92; Japan: 50, Germany: 0). All these examples concern projects from basic research which are related to biology or chemistry. As explained in chapter 2.7, in Germany there is no lack of personnel in these fields. On the contrary, many well-educated natural scientists have problems in finding employment whereas in Japan there is a general lack of human resources in the scientific area.

3.15.4 Constraints in the R&D System

Japanese and German experts' views on constraints in the R&D system are quite similar (see Figure 3.15-4) concerning the research and development system.

Figure 3.15-4: *Japanese - German comparison of the R&D system as a constraint on realization versus the time of realization (In Japan's case there are no topics with a forecasted realization time in the block of "1990-1994")*



The following are examples of long-term research topics, mostly in the Medical Care and Health area, which are judged to have high R&D systems constraint indices both for Japan and Germany. Examples for these similar assumptions are the *development of effective methods to prevent Alzheimer's disease* (J/G 15-16; R&D level index in Japan: 35, Germany: 20), the *possibility of imaging methods for differential diagnosis of mental diseases, enabling classification and determination of phases of schizophrenia, in particular, by imaging diagnosis* (J/G 15-34; Japan: 23, Germany: 28), and the *development of almost perfectly effective therapeutic drugs for schizophrenia* (J/G 15-63; Japan: 29, Germany: 39). It has to be found out by further investigation why the R&D system is regarded to hamper the realization of methods for illness prevention or therapies.

3.16 Comparative Conclusions for the Countries

Chapter 3 analysed the relationship among the expert knowledge, the importance, the time of realization, time variance, certainty, international co-operation, the R&D level, and constraints on the realization. Here, the various analyses made in the sections 3.1 to 3.15 are brought together and relevant trends are identified.

Regarding the relationship between importance and international co-operation, there is agreement between Japanese and German experts in the point that the need for international co-operation rises with the importance of the topic. The more important the technology is, the stronger is the need to promote that technology with a vision that reaches beyond national boundaries. This trend is a clear indication for the direction in which today's technology is progressing: the important technology today is *international technology*.

On the other hand, as for the relationship between importance and the R&D level, German experts consider their own level of R&D to be high in topics with a high degree of importance, whereas in Japan, no clear relationship between the two criteria can be identified. One explanation for this is that in Germany, a high priority is given to R&D in important areas of science and technology which - from the historical adjustment processes - resulted in a high R&D level, whereas Japan tackles a wide range of science and technology areas as a historical result of catching up.

The German experts seem to regard the R&D system as sufficient for the topics from the Delphi survey which were included because of their general importance. The most important of them (which influence the calculated indices more than the unimportant topics, see chapter 1.5) may have already attracted more attention by the R&D system whereas others which are nevertheless important because of lower general knowledge and a less developed R&D system are more difficult even to formulate for the Delphi and are, therefore, missing. If this were true it would point to the self-regulating mechanisms of the German R&D system which is probably more oriented towards an established state of equilibrium than in Japan with her very dynamic building-up phase.

Of course, the geographical environment makes it easier for Germany to co-operate in and share science and technology at various levels with its neighbouring European countries. There is no observable relationship between the necessity of international co-operation and the R&D level in Germany, however, in Japan, experts tended to indicate a higher necessity for international co-operation in topics where Japan has a low R&D level. Different factors are thought to contribute to this difference, first, Japan's geographical situation, in that the hurdles to implementing international co-operation, including language, are higher for Japan than they are for Germany, so Japan must be more selective and focus her international co-operation efforts on the technologies with a relatively inferior R&D level where the need for improvement is strongest.

Second, the fact that Japan was a nation that was always catching up to the most advanced "high tech nations" did require a strategy to learn from other nations. This attitude remained in the minds of many Japanese researchers although there is no reason for catching up, anymore, as Japan has already reached her aim of being one of the most advanced nations.

Third, the trend in which the R&D level is higher in the Practical Use and Widespread Use stages than in the Elucidation and Development stages is much stronger in Japan than in Germany, and also, being an island nation, Japan has less of a need for co-operation with other countries in technologies at the Widespread Use stage. In any event, differences do exist between Japan and Germany in views about international co-operation in science and technology, and both countries should keep such points in mind when seeking to strengthen international co-operation.

As for the relationship between time of realization, international co-operation and R&D level, similarly, the later the topic's time of realization the lower the current level of R&D, and, at the same time, the stronger the need for international co-operation. In this case, there is no sign of difference seen in the comparison of importance, international co-operation and the R&D level mentioned earlier.

This shows that while there are differences between Japan and Germany in importance in relation to international co-operation and the R&D level, there is general conformity in both countries' assessments of the time of realization. The reason for this general agreement on the time scale is thought to be that science and technology today has become so globalised that in most cases, information about overseas achievements and R&D progress can be obtained relatively quickly, even when the own country is not actively involved in the R&D of that specific field. In contrast, the degree of importance of a technology is a reflection of the national state of science and technology, and the national character itself, which is moulded by such factors as the socio-economic conditions or the history of the country.

As for the relationship between constraints and other parameters in the realization of the topic, major differences between Japan and Germany can be seen in the relationship between funding and human resources and the degree of importance. In Japan, as the importance increased, the percentage of experts that indicated constraints in funding and human resources rose sharply, while in Germany, there is no such trend. In the funding constraints, there is a need to take into account that the exact translation of what funding or capital shortage exactly means in German and Japanese language is difficult. These assessments are derived from personal judgements of Delphi panellists. No hard facts exist on the future and all limitations from the Delphi methodology (see chapter 1) should be kept in mind.

However, the difference between the two countries suggests that in Japan's case, there are still many aspects of major investments in long-term R&D, including funding and human resources that require improvement. This is underscored by the high percentage of Japanese experts that indicated these constraints in topics at the Elucidation stage, i.e. basic research. Regarding constraints in the R&D system, in both countries, the constraints index tended to rise as the importance of the topic increased, implying that the present R&D systems are not developed or upgraded enough to keep pace with the rapid progresses in science and technology. This makes science and technology foresight for priority setting even more important.

4 Cross Comparisons of Technological Topics on the Micro Level

4.1 Comparing some Important Innovation Scenarios

As discussed in the first German Delphi Report (BMFT, 1993), the 16 technology areas of the survey include various topics which could also have been included into different technology fields. Thus, for future innovation projects, conclusions from averages of the analysis are not always straightforward.

In this chapter, some examples of connected research problems are taken from different technological areas. The importance and expected time of realization of these topics are compared portrayed in scenarios. A scenario describes a hypothetical follow-up of events taking logical relations into consideration. Concerning technology assessment, a scenario can be regarded as the chronological order of events like a script for a film which is the literal meaning of "scenario".

To evolve a scenario, the experts' estimations are anticipated into inter-related future occurrences. Whether a scenario is "real" can be decided by a logical check of the chronology. To keep the context within the Delphi survey and to present paradigmatic scenarios with different characteristics, four scenarios were chosen from many more which would have been feasible also:

- Nanometer-size Structures
- Cancer
- Alzheimer's Disease
- Renewable Sources of Energy.

For every scenario, topics from different questionnaires of the survey were collected. For this choice, selected experts for the technology areas concerned were consulted.

The four scenarios are shown in figures 4.1-1 to 4.1-4. In these figures, the expected time of realization is matched against the accumulated number of selected topics (in per cent) so that one line for the Japanese and one for the German dynamic situation of the progress of solving the problem are visible.

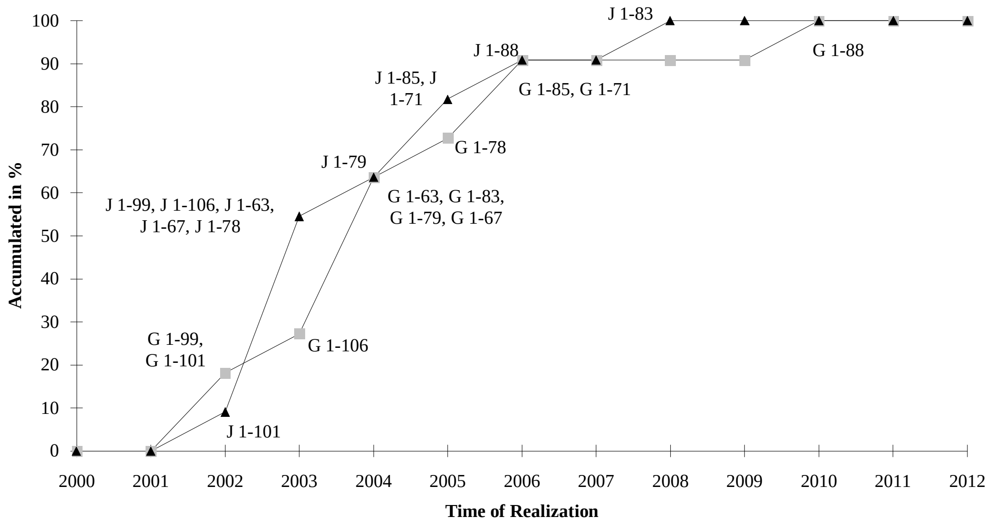
4.1.1 Nanometer-size Structures

A research theme which has recently gained significance is the area of small structures in mesoscopical chemistry and nano-technology. Nano-technology has a key function for the technological development at the end of the nineties and the first decades of the 21st century, because it allows engineering on an atomic or molecular level. For an adequate use of this technology, interdisciplinary collaboration with electronics, information technology, material sciences, optics, bio-chemistry, biotechnology, medicine and micromechanics is necessary.

To create the dimension of nanometers, structures and particles in this dimension must be available. Beneath the already known macro chemical effects, quantum effects will occur. Mesoscopical systems have a defined surface and a "life inside" whose principles have not yet been explained (Grupp, 1993, pp. 56 and 65).

Hence, the question for research is: Starting from molecular and solid state chemistry, it is assumed that particles and structures of nanometer-size are created which will have an increasing impact on parts of new solid materials and other future research problems (see, among other sources, DFG, 1992, p. 296).

Figure 4.1-1: Innovation scenario on nanometer-size structures



All eleven topics concerning nanometer-size structures originate from the technological area of Materials and Processing (Mat) and deal with all technology development phases of Elucidation, Development as well as of Practical and Widespread Use. In both Japan and Germany, most of the developments are expected to be realized between 2002 and 2006 (90 per cent of all questions). Therefore, the observer does not have the impression of a step-by-step progress but of parallel developments, many of which are realized during a very short period of time.

In most cases, only slight differences in the expectation of realization time between the countries can be noticed. The largest difference can be seen in topic J/G 1-88 concerning the *mass production of new materials constructed by using ions and particle beams with controlled characteristics*, which, in Japan, is estimated to become true as soon as 2006, whereas it is the last question in the German scenario (estimated for 2010).

Looking at the chronological order of realizations in both countries, at first, the *elucidation of adhesion mechanisms of metal-polymer interfaces* (J/G 1-101) takes place. In both countries, this is followed by the *use of processing technology for supersmooth metal mirrors* (J/G 1-99) with a one-year delay in the Japanese estimation. In Japan, the parallel developments for *embedding impurities and repairing crystallized silicon surfaces with STM (Scanning Tunnel Microscope) technology* (J/G 1-67) and *organic hybrid composite materials of controlled structure at the monomolecular layer level* (J/G 1-78) are expected in 2003 as well as the *widespread use of Atomic Layer Etching in semiconductors* (J/G 1-63) or of the *STM (Scanning Tunnel Microscope) or AFM (Atomic Force Microscope) for analysing molecular structures* (J/G 1-106). *Organic and inorganic composite materials with constituents in size of several to several ten nm* (J/G 1-79) are estimated to be developed in the following year, 2004.

In the German Delphi, some of these progressive stages are expected at the same time, e.g. J/G 1-79 and 1-106 or only one year later, e.g. J/G 1-67, whereas *organic hybrid composite materials* (J/G 1-78) are judged to be realized with a two-year delay.

The next two realizations estimated by the Japanese experts concern the *development of polymer processing technology for controlling micro structures in 1 to 10 nm size* (J/G 1-71) and the *possibility to control the structure and properties of solid interfaces at atomic level* (J/G 1-85). Both developments are expected one year later by the German experts.

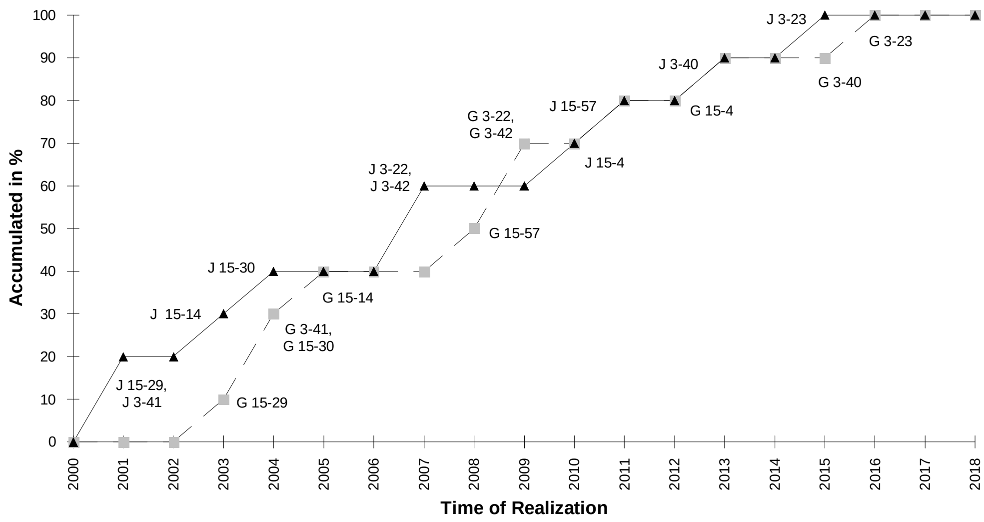
The most-delayed topics in Japan are the same as the already mentioned topics with the longest realization time in Germany (J/G 1-88) and topic J/G 1-83 (*development of techniques for synthesizing substances with new functions based on the combination of numerous types of bonds at atomic level*) which, in Germany, was expected to be realized four years earlier, in 2004.

The different topics that were chosen for the scenario on nanometer-size structures are not independent of each other and occur in parallel. We shall witness a breakthrough in nano-technology shortly after the turn of the century. It is based on progress in technology and manufacturing as well as progress in basic science. This is typical for a science-based technology.

4.1.2 Cancer

Considering the large number of cancer patients and deaths, the expectancy of progress in cancer research is very high. For the scenario on cancer, ten topics were selected, five from Medical Care and Health and five from the technological area of Life Sciences. The importance of all ten questions was rated as very high, some questions even appear in the Top 10 rankings on importance (chapter 4.2).

Figure 4.1-2: *Innovation scenario on cancer*



According to figure 4.1-2, progress in cancer research will drag on over a longer period of time than in nano-technology. The permanent development of technologies concerning cancer starts at the beginning of the 21st century. Both Japanese and German experts assume topics on diagnosis and prevention will be the first to be realized between 2001 and 2005. In both surveys, the first realization concerns the *practical use of diagnostic technology of cancer by using three-dimensional images* (J/G 15-29) but the German estimation is two years later. The second realization (in Japan: 2001, in Germany: 2004) would be the *development of sensitive techniques for simple and early cancer diagnosis using blood serum* (J/G 3-41).

The next realization from the Japanese point of view would occur in 2003 with the *enhancement of a secondary cancer prevention (early detection) system and social awareness of its importance, resulting in an average survival rate exceeding 70 per cent five years after the outbreak for all types of cancer* (J/G 15-14). For this topic, the German experts are a little bit less optimistic (2005), whereas there is the same estimation concerning topic J/G 15-30, *practical use of early diagnosis of* *cancer risk based on gene analysis and cytological means* (2004).

The following two topics are considered by the Japanese experts to be realized in 2007, the German experts are more pessimistic and expect them to be realized in 2010. One is J/G 3-22, the *elucidation of the whole aspect of signal transaction in the carcinogenesis of cells*, the other is J/G 3-42, the *practical use of effective means to prevent metastasis of cancer*. As this topic is the same as J/G 15-57, the different judgements of the science community from Medical Care and Health (Med, J/G 15) and those from Life Sciences (Lif, J/G 3) become obvious. The Japanese experts in Life Sciences are much more optimistic than those in Medical Care and Health (4 years earlier), whereas in Germany, the estimation of both science communities is similar (difference of one year) with slightly more pessimism in Medical Care and Health. It might be that physicians who are confronted with the practical application of prevention methods have become more disillusioned than the experts from the technology field Life Science who work more in the "ivory tower" of a laboratory than in hospitals.

The estimation of the last topics in Germany and Japan do not differ very much. *Medicines that prevent the development of cancer* (J/G 3-40) are not expected before 2013 (in Japan)/ 2015 (in Germany) and the *common use of medical treatment for dysdifferentiating carcinogenic cells* (J/G 3-23) not earlier than 2015 (Japan) or 2016 (Germany).

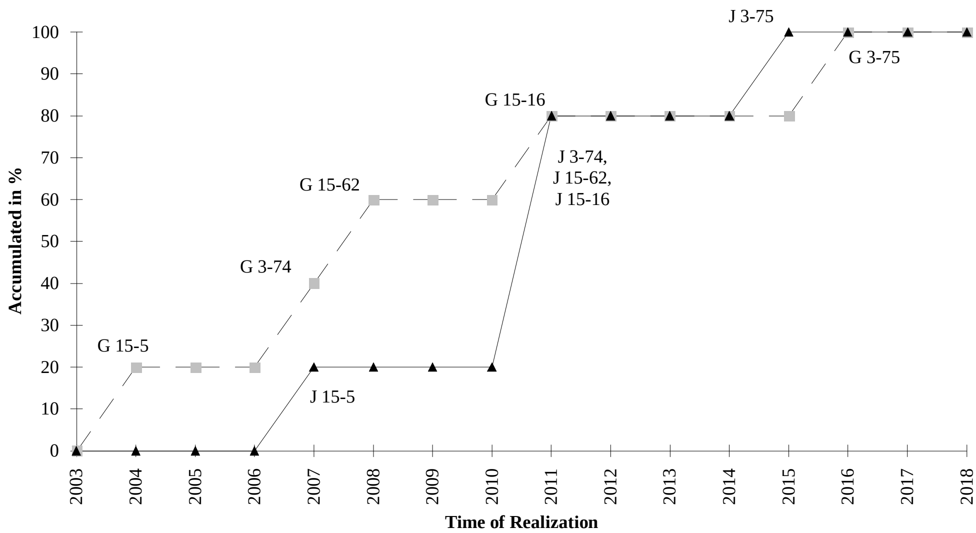
This scenario shows the predicted logical trends in cancer research: When diagnosis and prevention of cancer become possible, the first methods to cure the illness will be developed and some basic elucidation will take place (J/G 15-4, J/G 3-22) whereas prevention and treatment (J/G 3-40, J/G 3-23) will be realized very late. This means that in the immediate future, the success of cancer treatment still relies on an early diagnosis because a general cure still remains difficult.

4.1.3 Alzheimer's Disease

Alzheimer's Disease is having an increasing impact on society, especially in highly industrialised countries. As the population grows older, the number of Alzheimer patients increases. In Germany, for example, 80,000 persons suffer from this illness, which is named after the psychiatrist Alois Alzheimer (1864-1915). About 70,000 persons die of the disease every year.

In the Delphi survey, there were five topics on Alzheimer's Disease (figure 4.1-3) from the technological areas of Life Sciences (two questions) and Medical Care and Health (three questions). Unfortunately, there was no question on diagnosis. It can take a long time (up to 30 years) before such a latent disease can be diagnosed at all after the first signs of memory loss and impediments in thinking are noticed. One of the aims of recent research is to make earlier diagnosis possible and to prolong the phase before the first symptoms appear.

Figure 4.1-3: Innovation scenario on Alzheimer's disease



Comparing the judgement on time of realization for these topics, the Japanese experts seem to be more pessimistic: In both German and Japanese estimations, *the onsetting mechanisms of the disease are elucidated* (J/G 15-5) at first, in 2004 (German survey) or 2007 (Japanese survey). For the following four years until 2011, the Japanese experts expect no progress whereas the Germans estimate the *possibility of prevention* (J/G 3-74) as early as 2007 and an effective treatment in 2008 (J/G 15-62). These two topics and another one concerning effective methods of preventing Alzheimer's Disease (J/G 15-16) are assumed to be realized in 2011.

While the German forecast displays a chronological progression from the explanation of principles to prevention, cure and protection, the Japanese experts expect a breakthrough (realization of three topics) around 2011.

The last realization time in this scenario concerns the *healing of senile dementiae such as Alzheimer's Disease* (J/G 3-75) estimated for 2015 by the Japanese and 2016 by the German experts. Thus, the chronological order of time would be completed by the solution of the problem, the possible prevention, therapy and healing of Alzheimer's Disease.

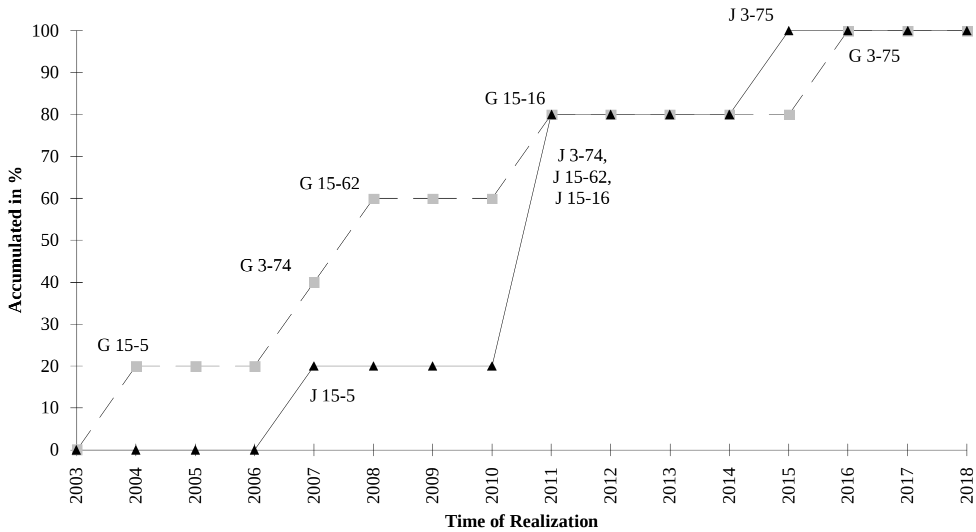
Altogether, this is a scenario with two distinct dynamics in Japan (breakthrough-type) and Germany (gradual progress). It is an open question whether the scientific and medical communities in both countries are really different with regard to their knowledge of the international progress in R&D in this field, or whether the knowledge base in the two countries is different because of insufficient communication.

4.1.4 Renewable Sources of Energy

The last scenario of this report is on renewable sources of energy and a more rational use of energy. The 13 selected topics from four technological areas (one from Materials and Processing, one from Life Sciences, eight from Energy and three from the field of Urbanization and Construction) are expected to be realized by 2013.

Whereas the dynamic is of the gradual type in both countries, this scenario is totally different from the one described above because in this technological field, the Japanese experts predicted the time of realization about 3 to 5 years later for every topic, although the chronological order of the realization is almost the same as in the German experts' judgement.

Figure 4.1-4: Innovation scenario on renewable energy sources



The earliest realization, which, in Germany, is expected as early as 1998 and in Japan in 2002, concerns the *practical use of a heating and cooling system through the combination of solar heat and super heat pumps* (J 12-52/ G 11-52). In Japan, the next progress assumed for 2004 is in the *practical use of large-area thin-film solar cells with a cell conversion factor of at least 20%* (J 8-12/ G 7-12) and the *practical use of a wind power generation system of a megawatt scale* (J 8-11/ G 7-11). The latter is foreseen by the German experts in 1999 and might be due to the very advanced research on this theme in Germany which was initiated by a high consciousness concerning environmental issues (green movement).

In Japan, the *widespread use of technology to process urine or excrements and various other livestock wastes for use as feed or fuel e.g., methanization* (J 8-18/ G 7-18) and the *practical use of distributed type house co-generation, utilizing fuel cells* (J 12-54/ G 11-54) are assessed to become real in 2005. Both topics are estimated to be realized two (J 12-54/ G 11-54) or three years (J 8-18/ G 7-18) earlier by the German experts. In 2006, *innovative passive solar houses which effectively use natural energy* (J 8-16/ G 7-16) may be realized from the Japanese point of view. In the German experts' opinion, these are already realized 5 years earlier (in 2001).

Nearly the same time of realization is predicted for the *widespread use of solar* *cells for residential power supply* (J 8-15/ G 7-15), in Japan the year 2007, in Germany, 2006. Another problem, the *widespread use of technologies that make it possible to treat and recycle wastes and the like at low cost by using bio-technologies and to collect energies e.g., in the form of methane* (J 8-17/ G 7-17) is expected to be solved in 2004 by the German experts, while the Japanese experts assume realization in 2007.

A very similar estimation is found for topic J 12-53 (2008)/ G 11-53 (2007) on the *advancement in technologies for effectively using energies such as the extended heat storages of natural energies, leading to dissemination of energy-independent buildings and houses*, which is the next topic in the Japanese order followed by the *practical use of technologies enabling solar energy to be converted into, or stored as biochemical energy* (J/G 3-29) expected in 2009. In this case, the German experts are - like in most of the other cases - more optimistic (forecasted time: 2006) as well as for the *widespread world-wide energy production using biomass as raw material* (J 8-13/ G 7-13), which shows the largest time-gap of 7 years (Japan: 2009, Germany: 2002) in this scenario. In 2010 in Japan, or as the German experts assume, in 2007 already, the *practical use of multi-layer solar cells with a conversion efficiency of more than 50%* (J/G 1-22) might be possible.

The last realization time expected by experts from both countries (in Japan for 2013, in Germany for 2010) is the *practical use of energy supply systems that convert clean energy into energy carriers such as hydrogen to transport them* (J 8-14/ G 7-14).

It is easy to see that these scenarios consist mainly of topics on Practical Use and a few on Widespread Use. Therefore, no breakthrough development in the chronological order as in the scenario on nano-technology can be expected. The topics on renewable energy sources concern solar cells as well as wind power, energy from biomass and the use of energy in buildings. This explains the order in time but not the earlier predictions of the German experts in some areas, which might be due to a different consciousness towards "saving energy" and renewable sources of energy evoked by the "green movement". The fact that the indices for importance in the 13 topics selected for this scenario are higher in the German than in the Japanese survey which underlines this assumption has to be analysed by further qualitative investigations.

4.2 Estimation of the Importance on the Micro Level

In this chapter, the estimation of importance in the Japanese and German Delphi surveys is examined. As described in chapter 2.2, the overall estimation of importance by the Japanese experts is higher than the German experts' assessment which is possibly due to the fact that the topics were created in Japan. For individual questions, however, higher estimates occur in Germany as well.

In the *index of importance*, all experts with high, medium or low expertise, who judged the individual topic, are taken into consideration. The average is shown as an index, for the calculation see chapter 1.3. For the comparison of the German and the Japanese survey, 1,146 topics could be analysed (see chapter 1.4 and 1.5). A warning should be provided. If groups of experts are in disagreement (see chapter 3.6), the average importance index cannot assume high values. Thus, the top important topics may be characterized by the fact that most experts agree on their outstanding importance. The top list represents collective assessments and may not include disputed topics that are highly esteemed by selected expert groups only.

4.2.1 Ranking by Importance in Japan and Germany

From the 1,146 topics of the Delphi questionnaire, a ranking from the highest to the lowest index in importance was made for the Japanese and the German side. The first ten topics of the Japanese Delphi are listed in Table 4.2-1. To show a list of only ten questions was an arbitrary decision because the following 20 or more questions might also have got a high evaluation of importance, but for reasons of space in this report not all topics can be mentioned. For a comparison, the German index of importance on the same topics is also given.

Table 4.2-1: Ranking of importance in Japan (Top Ten)

Six out of the ten topics in the ranking of important questions in Japan deal with safety or protection in general. The question on protection from air pollution was rated second of the most important topics (index 97). Environmental protection, health, protection from disasters and computer technology, are obviously given priority in the Japanese ranking.

Among the most important topics are three questions concerning cancer (J/G 3-42, J/G 15-4, J/G 3-12) of which one (J/G 3-42) is on top. This demonstrates the general concern about this illness which is one of the most frequent causes of mortality in Japan. Two topics are on environmental issues (J/G 16-10, J 11-30/ G 10-30) and one is dealing with security in air traffic (J 4-11/ G 13-11). Among the next important following no. 10 (not included in Table 4.2-1) this trend continues and topics on other illnesses like arteriosclerosis or Alzheimer's Disease would appear on the list if it were longer than 10 items.

Four of the most important ten topics are concerned with computer technology in general (*speed* in J 5-72/ G 4-26, *memory capacity* in J/G 2-3 and J 5-73/ G 4-27 and *processing of patterns* J/G 2-2) which demonstrates high priority setting of computer technology projects.

Only two topics deal with Elucidation (J/G 15-4, J/G 3-12), the other eight are application-oriented questions (Practical Use).

The top estimations of the German experts are similarly high, even higher than the Japanese (see Table 4.2-1 and 4.2-2). Three of the four questions on computer technology are not estimated to be as important in the German survey which illustrates the different priority setting in Japanese and German technology awareness.

Looking at the German ranking of the most important topics, the priorities of environmental protection and - in connection with it - the rational use of energy as well as the prevention of illnesses are obvious. Five of the high ranking topics are

Table 4.2-2: Ranking of importance in Germany (Top Ten) on environmental and energy issues (J 12-43/ G 11-43, G 11-51/ J 12-51, J 6-66/ G 5-66, J 12-53/ G 11-53, J/G 14-15 more indirectly) which demonstrates the German concerns about this theme. In three questions, the prevention of illness is regarded as very important. Among these are two topics on cancer (J/G 3-41, J/G 3-42) and one on the immune system (J/G 3-11) which can also have an impact on cancer research.

The development phases of the most important topics are mainly Development (3 questions) but also Elucidation (2 questions), Practical Use (3 questions) and Advancement (1 question), which is a phase equivalent to Practical Use and one on Widespread Use. This concentration shows an orientation towards basic research rather than broader application.

In general, the Top Ten questions in Germany also gained a high ranking in the Japanese estimation. The only exception is topic J 12-53/ G 11-53 with an importance index of 68 in Japan. This can be explained by a higher consciousness of saving energy and rational use of energies since the start of the "green movement" in Germany. Although there are and were many political and economic attempts in Japan to save energy, and in spite of the oil crisis of 1973 which was perceived as an "oil shock", a similar consciousness to that in Germany has not developed in the minds of Japanese people but rather a more pragmatic view of the necessity of using energy. It cannot be ignored that experts (as well as any other persons) are deeply influenced by a general shift in societal attitudes so that the different estimation in this topic reflects the changed cultural and societal background of the last 15 years.

4.2.2 Ranking by the Difference in the Importance

The topics with the largest differences in importance are listed in Table 4.2-3. A pronounced difference does not result from a very high estimation in the Japanese survey but by chance, among the Top Ten, only topics with a very low estimation of importance on the German side are represented. Another list of differences ranked according to the German point of view, in which the German estimation is high whereas the Japanese is lower, is explained in Table 2.2-2 of the BMFT-Delphi Report (1993, p. 88), but those differences are not pronounced in Table 4.2-3, here. They would appear on top positions beyond eleven (the largest difference in index values for which Germans credit more importance is 38, compare this to Table 4.2-3). Therefore, in this chapter, it has to be explained why the *German* experts refused or neglected these questions. *The Top Ten ranked by difference in importance are those with less emphasis in Germany in all cases.*

For reasons of space, only the ten most pronounced differences can be explained in this chapter, although, in many other comparisons, interesting facts could be detected. Most of the ten topics with a high difference in the estimation of importance are in the technological phase of Practical Use, two concern the Development of a technology and one Widespread Use respectively the Elucidation of a phenomenon. Many technological areas and a variety of themes from robots, agricultural themes, airplanes, nuclear power stations to brain mechanisms are represented. Hence, the topics have to be discussed one by one:

The question on *robots in homes or hospitals* (J 2-70/ G 2-71) shows the highest difference in importance. This is due to a very low estimation in importance by the German experts, although the Japanese estimation is not very high either. The reason is that the German experts - in spite of the lack of nursing personnel - do not want to be helped or nursed by machines if they were ill. In comments, the participants of the Delphi survey claim ethical reasons for that refusal and it is obvious that the fear that ill persons would only be physically treated by anonymous robots without consideration of their feelings made them neglect the topic. Some of the Japanese Delphi participants also criticised this question, but keeping the extreme shortage of personnel in Japanese hospitals in mind, most of the experts rated a higher importance. Of these persons, many did not think of direct nursing but of heavy work such as carrying persons, aiding them getting into the bath tub, assisting in cleaning rooms etc. which is better expressed in topic J/G 16-51 (in Table 4.2-3, too), in which the relevance on the German side is also estimated a bit higher (but still with 45 index points difference in assessment).

The question on *seaweed* (J 10-50/ G 9-50) gets a very low rating of importance in Germany because Germans do not eat seaweed as do the Japanese and, therefore,

Table 4.2-3: Ranking of the difference in the importance of topics (Only the top ten by difference) the experts see no necessity to cultivate it. On the contrary, many kinds of seaweed are a threat to the polluted and over-fertilised coastal areas in Europe. Germany is not an island like Japan where there are still undeveloped areas of sandy beaches, and the few German marine areas are used for tourism. For the Japanese, seaweed and other marine products are part of their main food sources and thus, the necessity of growing seafood is a real demand. As there is enough food available, Japan is not dependent on seaweed and the Japanese experts' estimation on the importance of using undeveloped areas for seaweed "pastures" is only medium.

The development of a *high-speed passenger plane* (J/G 14-44) was given a low assessment in the German Delphi because a country like Germany is not as dependent on planes as Japan, which is an island and larger (longer) in size. To go to a foreign country for Japanese people means crossing the ocean (by plane or by ship) and as the most important trade partner is the USA, the importance of crossing the Pacific is *relatively* high (with 67 index points, the importance is nevertheless only on a medium level). The German experts, as the comments show, always keep environmental issues in mind and refuse such planes because the sky (especially in Europe) is already overcrowded and planes pollute the air more than other means of transport. Therefore, in their opinion, the current planes are sufficient.

Fishing methods (J 10-56/ G 9-56 and J 10-57/ G 9-57) have a decreasing significance for the economy in Germany (problems within the European Union) and for eating (Japanese people eat more fish than Germans) as well as because of the lack of fishing grounds. The ecological reason behind the German experts' thinking is - according to the comments - that the seas are already "over-fished", which means the species have to be protected instead of developing new methods for catching them. Therefore, the German experts judged a low importance.

Artificial islands (J 6-18/ G 5-18) are not relevant in Germany because there is not enough "German sea" for them. In addition, the use for processing waste seems to be too dangerous for most of the ecologically-oriented German experts, not only for the coasts, but also the whole ecological system of the sea which could easily be destroyed by dumping (even "harmless") parts into the water.

The topic on *nuclear power facilities* (J 8-25/ G 7-25) is not rejected because of the innovation in *automation* but because of a general opposition to nuclear power. Since the accident at Chernobyl, which had a large impact on Germany (because of east winds) and demonstrated the always present dangers of nuclear power technology, there are experts who oppose the technology in general (and estimate it as unimportant) and those who still rely on it (and argue for its importance). The tendency in Germany is to "get off" this technology and therefore, the automation, which is considered to cause additional dangers, is regarded as less important than in Japan.

At first sight, it seems to be astonishing that *optical computers, equipment* and the like (J 11-58/ G 10-58) are on this list of topics with the largest difference in importance and seem to be rejected by the German experts. But the second half of the sentence, which in the English translation is more moderately expressed as "resulting in the emergence of super information-intensive society", was translated directly from the Japanese as "total informierte Gesellschaft" (totally informed society) in the German Delphi and because of the radical and negative connotation of "total" was regarded as irrelevant and undesirable. The word "total" was used because it is the equivalent of the Japanese "totaru" (same sound and meaning) but, in the Japanese context, it is not regarded as negative to be "totally informed" which, in the Western context, sounds like "overall supervision" and is reminiscent of George Orwell's famous novel "1984". (Because the problem was known to the Japanese Delphi team after the German experience, the English translation avoided the word "total".)

The *elucidation of the human decision-making mechanisms* (J 2-81/ G 2-82) is - from the German point of view with its experience of the Third Reich - very dangerous, because this kind of knowledge can be used to influence human beings in a negative way. Therefore, many experts judged this topic as "unimportant" but, in many cases were obviously thinking of the undesired effects that could occur. Nevertheless, other experts regarded it as important so that a medium average was achieved for the German Delphi which did not come close to the Japanese estimation but is not as low as the other discussed topics. In Japan, brain research in general is of major importance because of the "decade of the brain" and is therefore regarded as very important (84 index points).

As could be shown in this chapter, not only technical considerations lead to the judgements of the individual experts but political, historical, societal, cultural and economic factors also influenced the estimation of the topic's importance. In some cases, importance is not judged solely on the basis of "technological relevance" but subjective considerations and fixed opinions may have the same impact on the evaluation as objective reasons. This has to be kept in mind when regarding the comparison on the criteria of importance.

4.3 Forecast of the Realization Times on the Micro Level

4.3.1 Near Future

In this chapter, topics are discussed which were predicted to have an early time of realization. As described in chapter 2.3, 5-year-steps were asked for (until 1995, 1996-2000, 2001-2005, 2006-2010, 2011-2015, 2016-2020 and after 2020). From these predictions, a time variance was calculated ranging from a lower quartile (time estimated by 1/4 of the responses) to an upper quartile (forecast of 3/4 of the experts). Between these estimations the median indicates the year until which half of the answering experts expect the innovation to be realized (for the calculations see chapter 1.5). The median therefore represents the most probable realization time (consensus). As it is a table which is more precise than the original five-year periods, it can be ranked. The rankings shown take the first ten median estimations of all Delphi topics into account (Top Ten). To compare only ten topics might be considered an arbitrary decision but the ranking had to be limited for reasons of space in this report.

Some of the early topics may have possibly already been realized. In some cases, the experts were assuming in their comments that the given technology is already in use. This might be true for a special variant but not for the more general purpose the Delphi survey asked for. In such a case, the lower quartile may show a time before 1993, but the topic in the manner given has not yet been realized.

This chapter does not want to explain who is right or wrong in his or her estimation of the time of realization but tries to discover why most of the experts from one country judged differently from those of the other. The future will show when and if a technology can be realized at all. In many cases, it is difficult to assess if, at the given time the technology has really become true i.e., in the case of Widespread Use of a technology, it is difficult to determine the month or year when this phase starts.

Table 4.3-1: Ranking of early realizations in the German Delphi survey by topics (Top Ten)

The authors of this report are sure that there are topics which, in the meantime (the surveys took place in 1991 and 1992, respectively), have already become reality, which might have been overlooked in some cases. Therefore, the authors would be grateful if any reader of this report who knows about such a realization could inform the Delphi teams at ISI or NISTEP about this.

In the German estimation, eight of the ten early predictions belong to the technology area of Marine Science and Earth Science, one to Transportation and one to Communications. Most topics concern the innovation phase of Practical or Widespread Use, two questions are on the Development of a technology which underlines the difficulty of foreseeing breakthroughs and developments.

The use of a *GPS* (*global positioning system, J 6-50/ G 5-50*) is expected for 1993 with a very small variance in the time of realization and a relatively high estimation of the certainty (index 71 with high precision). At first sight, this seems to be astonishing but the experts were right: In 1993, there were newspaper reports on GPS which was used for height measurements. By applying this new method, it was found that the height of Mount Everest, the highest mountain on Earth, had not been measured precisely until now. The same results occurred when mountains in Switzerland were measured. The use of a GPS was, in the Japanese estimation, forecasted for 1998, also a very early forecast and no. 2 of the Japanese Top Ten (see Table 4.3-1).

The next early forecasts concern monitoring and observation (J 6-72/ G 5-72, J 6-51/ G 5-51, J 6-37/ G 5-37, J 6-46/ G 5-46, J 6-49/ G 5-49, J 6-10/ G 5-10, J 6-42/ G 5-42). They are all from the technological area of Marine Science and Earth Science. The first of these topics concerns technology for monitoring snowfall, which is estimated to be realized during 1994 in the German survey (with only a small time variance). Alongside technical constraints and costs, some experts mentioned an inefficient R&D system. For this topic, the Japanese estimation is much more pessimistic (8 years later) and apart from institutional and cultural, all kinds of constraints are supposed to hinder the realization. 1994 is the issue year of this report. The authors do not know the present state of snowfall monitoring.

Rank number 3 also has something to do with monitoring, but is more concerned with the construction of a measurement tool, a *gravimeter* (J 6-51/ G 5-51). The time variance in the German estimation is relatively small (7 years) and fewer technical than cost constraints are asserted whereas the Japanese experts expect a later realization in 2000 (with a similar time variance) than the German experts (1995) because of mainly technical but also other constraints. As the certainty in the German estimation is much higher and more high-knowledge experts answered this question, one might assume that the German experts know better. Time will show who made the "better" prediction.

The *widespread use of undersea robots for observation purposes* (J 6-37/ G 5-37) is also expected for 1995 in Germany. Time variance is relatively small and precision of the estimation relatively high. Thus, it is astonishing that the Japanese experts expect this realization 7 years later with a similar degree of certainty but a broader time variance (discord). In both cases, mainly experts with a medium or lower degree of expertise answered the question. Perhaps, the experts of Marine Science in both countries do not feel specialised in the development of machines.

Short-term forecasts of very intensive rainfall, snowfall, and other sharply localised phenomena using improved radar observation network and data processing technology (J 6-46/ G 5-46) will be possible in 1995 according to the German Delphi with a relatively high certainty and small time variance. This estimation is slightly more optimistic than the Japanese, who expect the realization for 1999 but with a lower precision (degree of certainty and time variance). All kinds of constraints (except in the German survey "Human Resources") are mentioned, so that it is not clear whether only technical reasons hinder the realization or whether the use of such a technology is already possible but other reasons hinder this implementation.

The same can be observed for *long- and short-term weather forecasts using remote sensing technology* (J 6-42/ G 5-42). This is expected to be realized in the year 1996 with the same assumption of the realization time as the above mentioned question in Japan (1999). All kinds of constraints are mentioned for this topic so that it is not clear whether the use of remote sensing is the problem or whether it is its application to long- and short-term weather forecasts. In order to find the reason, further investigation would be necessary.

Similar estimations in Germany and Japan are made for a *marine observation* *system using amphibious aircraft* (J 6-10/ G 5-10). In this case, the hindrance is not the technical possibility but costs and funding (mentioned in both surveys) because several kinds of amphibious aircraft already exist, but are not used for the purpose in this topic. Thus, the early realization (relatively early in both countries) is not dependent on any more technical developments, but on financing this particular use.

Surveys based on the inertial system using a gyro and accelerograph (J 6-69/ G 5-49) are also possible in 1995 (median estimation) from the German point of view. In Japan, this is expected to become reality 6 years later. Astonishingly, the relatively small time variance of the first round was broadened in the German estimation in the second round although the very few respondents (12 for the first, 5 in the second round) assumed a higher precision in the second round. Perhaps this early estimation is not representative and is a statistical artefact because the Japanese number of respondents for this individual topic was much higher (71 for the first, 65 in the second round) than the German.

In the following year, *flying boats for regular service transportation between cities or to isolated islands* are supposed to be in practical use (J 14-43/ G 14-43). This is stated with a high certainty in Germany (degree of certainty and time variance). The Japanese experts expect this topic to be realized 10 years later without such a high degree of precision. The "flying boats" in the German Delphi survey are translated as "Tragflächenboote" with the more concrete annotation of "Hydrofoil, Airfoil", which already exist, so that the German experts seemed to have made judgements based on the existence of the technology rather than on the application *for regular service transportation*. German experts claimed mainly cultural reasons as a hindrance to realization (transport at sea would be a very rare occasion inside Germany) whereas the Japanese see mostly financial constraints. This might be the reason for their late expectation and, as the economical background for the application of such a technology is the most important factor, their judgement seems to be reasonable as well.

The development of certain anti-hacker devices (J 13-48/ G 12-48) is also expected to be possible in 1996 in Germany. The Japanese experts are more pessimistic and estimate the year 2000 for the realization. German experts seem to be very sure (relatively high degree of certainty and small time variance) about their estimation, but expect all kinds of hindrances, especially technical constraints. The Japanese experts seem to be not as confident (broader time variance and low degree of certainty) and expect mainly cost problems apart from technical ones. It cannot be judged who is right or wrong. Some anti-hacker devices already exist and are used without any technical problems but hackers are very clever at finding ways of by-passing such devices after some time so that the development of generally applicable devices might be regarded as very difficult and time-consuming.

Regarding the earliest ten Japanese estimations, three of the ten topics are from the technological area of Marine Science and Earth Science, three from Transportation, two from Communications and one each from Environment, and Culture and Life-styles. All the topics are in the innovation phase of Practical or Widespread Use which underlines that it is easier to predict the realization time of a subject that does not long for a breakthrough solution.

The first realizations in Japan are expected in 1998. This is about five years later than the first German estimations. The very first topic (J/G 14-5) concerns *railcars capable of continuous operation at a speed of 300 km/h while still meeting environmental standards, using today's trains' facilities and equipment*. The degree of certainty and the time variance demonstrate a high reliability of this estimation. The German expectation is much more pessimistic (2003), but this is not due to the fact that trains play a more minor role than automobiles in this country. On the contrary, the ICE, the German equivalent of the Japanese Shinkansen, has improved the infrastructure and acceptance of trains in Germany to a large extent. It is technically already possible to use *trains* with a speed of 300 km/h in Germany as well as in Japan, but trains are not *railcars* and *meeting the environmental standards* is the major problem. Trains are very noisy and a solution to this problem is not yet in sight. The difference in the Japanese and German estimation may also result from the interpretation of the vague expression *environmental standards*. It is unknown which kind of environmental standards are meant, which standards are regulated in Japan, which in Germany and if they are comparable. Therefore, a difference in the estimation could have been expected.

The second-ranking question in the Japanese estimation is the already mentioned GPS (J 6-50/ G 5-50). For the discussion, see above.

Table 4.3-2: Ranking of early realizations in the Japanese Delphi survey by topics (Top Ten)

The next two topics in the Japanese estimation are from the Communications area. They concern *small telephones* (J 13-23/ G 12-23) and *spread spectrum methods for consumer communication networks* (J 13-1/ G 12-1). The assessment of the time of realization is exactly the same in Japan as in Germany with a similar estimation for time variance and the degree of certainty. Only the technical constraints in question J 13-1/ G 12-1 are assessed higher in Japan. In the telecommunication area, the information level seems to be similar in both countries and no differences exist between them so that the same judgements are made.

Nearly the same assumption is made in Japan and Germany on the *use of materials that replace fluorocarbon and halon, that do not damage the ozone layer and cause no global warming problem* (J 9-4/ G 8-4), 1998 in Japan and 1999 in Germany. This early estimation in both countries is explained by comments of the experts which demonstrate that many materials already exist which can replace fluorocarbon and halon but that it is a question of costs, the regulative framework-conditions and the fear of dangers caused by newly developed materials. For some purposes, new solutions still have to be found and, therefore, the median judgement is for 1998 and not for now.

The following two topics on *weather forecasts* (J 6-42/ G 5-42 and J 6-46/ G 5-46) have already been discussed in the context of the German Top Ten. They are expected to be reality later in Japan, but still belong to both countries' early estimations (Table 4.3-1).

The two questions from the technological area of Transportation which are both estimated to be realized in 1999, are expected by the German experts in 2004. The first one is *the practical use of systems to detect people, cars, or other obstacles on tracks and automatically brake trains, using lasers or ultrasonic technology* (J/G 14-7). The precision of the forecast is claimed to be similar (degree of certainty and time variance) so that the difference in the predicted time of realization might be due to the different assumptions on constraints. The experts of both countries assume high technical constraints, but only the German experts judge that high costs will hinder the realization of this detection system which might be the reason for the later estimation in the German Delphi.

The second topic of Transportation is the *widespread use of tyres for the cold season which provide the same road surface gripping capability as spiked tyres but do not cut roads* (J/G 14-21). The degree of certainty and the time variance are medium for both the German and the Japanese estimation. The experts claim mainly technical constraints. In Japan, the costs are also estimated as a major constraint, and other hindrances would in their opinion occur as well whereas the German experts mention an insufficient R&D system. This might be the major reason for the later estimation on the German side, where costs are not considered a constraint on realization.

The last topic that can be mentioned from the early Top Ten are *artificial products that provide a touching sensation similar to that of natural substances such as mink to aid the conservation of nature* (J/G 16-24). The time of realization for this topic is judged in both surveys as 1999. As artificial products already exist, the assumption that those which provide the touching sensation will be realized at an early time seems to be a logical progression. In both countries, cultural factors play a major role as a constraint on the realization, which means that these products could be realized earlier but their acceptance will (for cultural reasons) remain a problem.

To summarise, one has to notice that all the first estimations of the time of realization are earlier in Germany. Some of the topics that are judged to be realized early also appear in the Japanese Top Ten but at a later time of realization. Among the Japanese early estimations are many topics that have the same expectations regarding time realization as in Germany but do not appear in the Top Ten because there are other topics which are expected to be realized even earlier. Thus, the large differences in early realization times that were noticed at first glance, disappear when examined in more detail. Certainly, more reasons could be discovered by deeper and more detailed analysis of the different technologies, i.e. interviews, patent statistics for related technologies, literature analysis and the like, but this cannot be provided in this report.

4.3.2 Distant Future

Comparing Japanese and German data, the predictions of late realization times are not as different as the early predictions. This might be due to the fact that only the median is shown in the rankings of this report. For those topics which are estimated to become reality around 2020, many experts estimated the category > 2020. These predictions were calculated as 2022.5; i.e. as an artificial five-year period for calculation reasons, not taking into account that some experts thought of a later realization time (open interval). Based on their comments, several experts assume, that the particular item will never be realized. Thus, many topics which are estimated to be realized after 2020 were given a too precise and too early median for their evaluation; however, this should be sufficiently correct as a ranking criterion.

The late forecasts are very similar in Germany and Japan. Six of the Japanese Top Ten in the ranking can also be found in the Top Ten of Germany.

In the German Top Ten, three topics are from the technological area of Particles, the other ones each from Space, Mineral and Water Resources, Culture and Lifestyles, Transportation, Information and Electronics, Life Sciences and Energy. Most topics require a breakthrough solution and therefore ask for Elucidation or Development, only two questions concern Practical Use (J 7-36/ G 6-36 and J/G 14-59).

The estimation which was last in Germany and also very late in Japan was made for the *development of technologies for producing and storing antimatters and energy sources which use them* (J 5-61/ G 4-15). Nothing can be said about the time variance in the German estimation, because the upper quartile is an open interval and the lower quartile is just at the border of an estimation of approx. 2020. Nevertheless, this means that about one quarter of German experts forecasted the period 2016 - 2020. The precision of this forecast is estimated to be low, which is typical for topics that are expected to be realized very late and additionally, require or need a breakthrough solution. In the Japanese estimation, the precision is somewhat higher and the lower quartile earlier which again means that there are 1/4 of the experts expecting a realization earlier than 2021.

Table 4.3-3: *Ranking of late realizations in the German Delphi survey by topics (Top Ten; the given median years are calculated with the wrong assumption of a closed interval 2020 - 2025. They only represent the ranking criterion and should not be taken literally.)*

The second topic is on *manned laboratories on Mars* (J 4-7/ G 13-7), which are not expected by either country before 2022 with low certainty in the German and slightly higher in the Japanese survey (for a further explanation see below).

Sub-lightspeed ion beam propulsion rockets (J 5-60/ G 4-14) are not assumed to be realized before 2020 in Germany and in Japan. This topic is also represented in the Top Ten of Japan. The experts in both countries are not very sure about their assumption (low degree of certainty) and as the chart on quartiles and median has an "open end" nothing can be said about the upper quartile and time variance in either country.

A difference in the estimation can be noticed for topic J 7-36/ G 6-36, the *practical use of international water transfer systems to enable a stable supply of water*, which will not be realized before 2020 in the German estimation but is predicted for 2015 in Japan. The experts of both countries are not very sure about their estimation (relatively low degree of certainty). While the German experts evaluate a very high necessity of international co-operation on this matter, the Japanese estimation is only medium. This might be due to the geographical situation of both countries. Germany, in the centre of Europe, is dependent on many countries where water is concerned, whereas Japan is an island and relatively independent. For this reason, the estimation of international co-operation as well as the time of realization might be different. The second reason might be the different estimation of the constraints. Whereas the Japanese see mainly institutional and some cultural and cost obstacles, the major restrictions in Germany are regarded as being technical as well as cost and funding constraints.

The next two judgements (J 5-86/ G 4-40 and J/G 16-56) of the Top Ten ranking are very similar and are also represented in the Japanese Top Ten list. The precision is very low in Germany and only a little bit higher in Japan in both cases. In both countries, very few experts answered the topic (except J 5-86/ G 4-40 in Japan). Technical obstacles will hinder realization, some presuppositions will maybe have to be elucidated first e.g., for J 5-86/ G 4-40 the presence of neutrino mass has to be proven or for J/G 16-56 elucidations from sleep research are necessary before these two topics, which were often regarded as "Science Fiction", will be realizable.

The *practical use of new, small urban transportation systems which freely enable trips between high-rise buildings through air corridors* (J/G 14-59) is the topic with the largest difference in the estimation of realization time. Whereas most of the German experts do not expect the realization before 2020 (median), the Japanese predict the realization for 2011. In both countries, a high time variance and a medium or low degree of certainty are given. This might be due to the fact that, in Germany, high-rise buildings are not as ubiquitous as in Asia and the necessity for such a transportation system is not as high as in Japan. A necessity to co-operate internationally exists in Japan as well as in Germany, where such a transportation system is not yet relevant. The major obstacles in Japan are costs and institutional constraints whereas very few hindrances are seen in Germany. The late prediction here seems to be due to the fact that there is no necessity for this development and therefore not much thought has been given to this theme.

The *elucidation of the decision-making mechanisms of the brain* (J 2-81/ G 2-82) is not expected before 2020. In both surveys, the time estimation is not considered very precise and the time variance shrank during the second Delphi round but remained relatively broad. Technical obstacles are the major reason for delay in Japan as well as a lack of human resources. In Germany, cultural factors more than technical constraints are the limiting obstacles. This corresponds to the assumptions of the importance of that topic (see chapter 4.2). Although this is one of the questions with a major variation in the estimation of the importance, the foreseen time of realization is not that different. However, due to the calculation of the median (see above), the figures cannot be interpreted differentially.

The *development of technologies for synthesizing organisms that have self-multiplying functions* (J/G 3-33) is not expected before 2020 in both countries with a low precision of estimation. In both countries, this topic is evaluated as not so important and mainly technical constraints will hinder its development.

The last of the German Top Ten ranking concerns the *fusion reactor* (J 8-23/ G 7-23) which will not be possible before 2020. In both countries there is a medium certainty of prediction and technical problems as well as financial constraints are seen as the main reasons for the late realization.

Table 4.3-4: *Ranking of late realizations in the Japanese Delphi survey by topics (Top Ten; the given median years are calculated with the wrong assumption of a closed interval 2020 - 2025. They only represent the ranking criterion and should not be taken literally.)*

The Japanese late estimations are similar to the German estimations and parallel to that list. Again, some topics do not appear because they are placed at rank No. 11 and downwards in the Japanese list and so just miss being included in the table, but the judgements involved are very similar to those of the German experts. Six of the late realizations in the Japanese Top Ten list have already been discussed in the German list (J 8-23/ G 7-23, J/G 16-56, J 4-7/ G 13-7, J 5-61/ G 4-15, J 5-60/ G 4-14 and J 5-86/ G 4-40). They are not repeated here with the exception of topic J 4-7/G 13-7.

Four of the ten questions are from the technological area of Particles, and one each from Energy, Culture and Lifestyles, Urbanization and Construction, Space, Transportation and Life Sciences.

Rank No. 1 in Japan is the *construction of proton decay detectors of the million ton class on the lunar surface* (J 5-82/ G 4-36) with a similar estimation in Germany. In both surveys, the forecast is not very precise and technical constraints and insufficient funding hamper the realization.

Ranks No. 3 and 4 have already been discussed, but the following two ranks are interesting because they share the same context. As discussed above, the *Erection of a manned laboratory facility on Mars* (J 4-7/ G 13-7) is not predicted to be realized before 2022 in either country. But the same topic in a different technological area (J 12-14/ G 11-14) is expected in 2016 by the German experts of the Urbanization and Construction field whereas their Japanese colleagues in this field make exactly the same judgement as the Space experts. The few German experts from the Urbanization area who answered the topic admitted a very low degree of certainty but assessed the topic in the same way (small time variance). In the other science communities, the precision is medium to low, but not extreme, so one can assume that the earlier forecast is based on the lesser knowledge (most of the few experts involved admitted their lack of knowledge) of the German experts from Urbanization and Construction.

Underwater monorails (J/G 14-36) are predicted as late in Japan as in Germany with a medium or low estimation of precision. Technical and cost constraints but also low importance hinder an earlier realization in Germany, the slightly higher evaluation of importance in Japan did not improve the result.

A slight difference in the forecast can be seen in the topic on the *elucidation of mechanisms of higher mental activity responsible for intuitive solutions of problems* (J/G 3-68). The precision of the forecast is low in both cases, but the German experts do not perceive as many technical constraints as the Japanese. This might be the reason for their earlier estimation. The degree of expertise in both countries is also relatively low.

It is obvious that breakthrough solutions are more open to speculations on the distant future than Practical or Widespread Use. In most cases, the major constraint on the realization can be found in the technical area. For the late topics, German and Japanese predictions are approximately the same and in both countries, such visionary technologies are often considered science fiction.

4.3.3 Large Differences in the Realization Time

The largest differences in the time of realization are calculated by comparing the median of the topics in Japan and Germany. The difference does not necessarily show an early or late time of realization estimated by the Japanese or German experts. For five topics, Japanese experts estimated an earlier time of realization, for the other five, the assumptions of the German experts were earlier.

Three of the ten topics with the largest difference are from the technological area of Agriculture, Forestry and Fisheries, two from Information and Electronics and the others are from Urbanization and Construction, Production, Culture and Lifestyles, Transportation and Life Sciences, respectively. Differences are identified for questions concerning Elucidation as well as Development or Practical and Widespread Use.

Table 4.3-5: Ranking of the largest differences between the estimated time of realization in the Japanese and the German Delphi by topics (Top Ten)

The greatest difference concerns a topic on space exploration which, in the field of Urbanization and Construction asks for *facilities by which ordinary citizens can stay in space for an extended period of time* (J 12-13/ G 11-13). The time variance in both cases is very broad, and is even broader in the first Japanese round. The certainty of the estimation is low in the German survey and medium for the Japanese. The question was answered by only a small number of experts with a very low self-estimation of expertise on the German side, whereas the number of answers and the degree of expertise is higher in Japan. It cannot be judged who is right or wrong yet, but the more pessimistic data on the Japanese side are based on a higher degree of expertise. The Japanese experts expected technical constraints as well as funding obstacles, whereas the German experts only assumed slight constraints on the cost and funding side and hardly any technical obstacles.

The next greatest difference concerns the *seaweed "pastures"* (J 10-50/ G 9-50) which are predicted to be realized very late in Germany, whereas the Japanese experts expect a realization 16 years earlier. This was also one of the topics with the greatest difference in the estimation of importance (chapter 4.2.2). Because of the reasons mentioned (Germans do not eat seaweed and there is not much marine space around Germany), hardly any experts could be found in Germany, so that the few respondents have a lower reputation and are not very confident about their statements. The time variance is very small, but this is due to the fact that only a few persons answered the question in Germany and is not an indicator of high precision, whereas in Japan, the number of respondents was medium and hence, a broader variance appeared.

Rank no. 3 is a topic on the *elucidation of sensations* (J 2-100/ G 2-101) which is predicted 16 years later in Germany than in Japan. The certainty on the time assumption is evaluated slightly lower in Japan than in Germany but no conclusions can be drawn from this. The degree of expertise is also similar. Concerning the constraints, higher obstacles are expected on the Japanese side so that it is remarkable that the German experts forecast such a late realization even though they do not expect many constraints on realization. For a more detailed explanation, further analysis would be necessary.

The *possibility of managing large scale migratory living marine resources* (J 10-59/ G 9-59) is expected 16 years earlier by the German experts than by the Japanese.

One reason for this difference might be that only a small number of experts with a more medium degree of expertise answered the question in the German survey. The time variance given is very broad and the certainty of estimation is low, so that the answer may not be representative. As constraints are mentioned technical and the R&D system as well as institutional, cost, funding and others, all on a lower level. The precision of the Japanese answers is not very high, either (broad time variance and medium and low degree of certainty), but there is a higher expectation of technical and cost constraints. The R&D system is also mentioned as a constraint. In this case, the large difference might also be due to a difference in the translation or interpretation of words. The Japanese word "Kanri" was translated as "Überwachung" (supervision) in German, but it can mean "supervision" as well as "active control" or "management/administration" which involve a higher degree of difficulty than passive "supervision", so that the later estimation might be the result of a different comprehension of the matter in question.

The topic concerning *advancement in the research into image communication* (J 11-59/ G 10-59) is not unambiguous so that the large difference in the estimation (15 years) might result from a different interpretation of the word "advancement", as the starting level for the advancement is unknown. Advancement from a higher level is different from advancement from a lower level. The German experts seem to be relatively sure about their prediction (small time variance and medium degree of certainty), whereas the Japanese experts' forecast shows a very broad time variance. Technical obstacles are, in both cases the major constraint. The Japanese experts also mention cultural constraints concerning the difficulties with the Japanese language consisting of characters and syllables which require a much higher degree of image processing than alphabetical communication.

Decomposing the constituents of odours (J/G 16-54) will be possible in 2003 from the Japanese point of view, whereas the German experts expect it 15 years later. The time variance was very broad in the first German round but shrank during the second round. The certainty of the estimation is very low in the German survey, and may be due to the low degree of expertise of the respondents who judged this topic as having only minor relevance. This might be the reason for the late forecast. The Japanese participants' expertise is also quite low, but their certainty is higher than the Germans'. The time variance was also much broader in the first round than in the second but while the German experts expected only a few constraints, the

Japanese mention technical and cost obstacles. This has no logical reason and cannot be concluded from the Delphi itself. Thus, further investigation would be necessary to find out why the judgement is different.

Commuter and business sea traffic transportation network systems (J/G 14-28) are topics which are more relevant for Japan, so that the earlier prediction of the realization time in Japan (2005) than in Germany (2019) is logical. Although the German experts are as confident about the precision (certainty) and mention less institutional and cost restraints than the Japanese, their estimation seems to be reasonable. Where should the widespread use of such a system take place in Germany and which big city is close enough to the sea to use it? Thus, the German estimation is not surprising, considering the possibility of application in Germany.

More surprising is the early forecast of the German experts on the *practical use of technologies for using a large volume of deep water for new fishing grounds in the open sea* (J 10-52/G 9-52) because the Japanese are supposed to be more expert in fishing, having the largest number of fishing boats and the greatest experience in deep water fishing. However, the number of German respondents is very low, only a few experts are available and their judgement is not very precise, so that this early estimation seems to be of low statistical quality.

The pessimism regarding the *practical use of systems to guard information from destruction or loss due to natural disasters or human intentions* (J 2-89/ G 2-90) which results in a late prediction of realization on the German side can be explained by the complexity of the whole problem, which is often discussed in Germany in the context of data, information, hacking etc. Concerning the protection of data and information, the Japanese seem, in general, to be more optimistic than the Germans, e.g. about data security or misuse by other people. Thus, the earlier expectation of such systems makes sense. Estimations on certainty, importance or constraints are similar in the Japanese and German surveys so that no other conclusions can be drawn without further investigation.

The difference of 13 years in the forecast concerning the *practical use of plants storing carbohydrates in high concentrations as a fuel source* (J/G 3-82) is less explicable, because the estimations on the degree of certainty, expertise and importance are similar. Only the time variance is broader in Japan, which indicates uncertainty; and technical and cost constraints on realization are evaluated somewhat higher than in Germany, but this is insufficient for a sound explanation of the reasons behind this difference. The present state of this development and the scientific community working on the topic would have to be analysed in more detail before attempting further explanation.

To summarise, a variety of reasons may contribute to early or late predictions in one of the two countries: cultural peculiarities, a different estimation of the constraints on realization or simply statistical artefacts resulting from a low response rate in the Delphi survey. Concerning the differing estimations, the future does not necessarily show who is "right" or "wrong" as an alternative technology may replace the one in question. If a prosperous line of scientific or technological development is abandoned, then the present assessment cannot be checked. Regarding the early and late estimations in both countries, a certain consensus could be found in the assumptions on some of the technologies, whereas others displayed contrary opinions about the realization time. The reasons for the differences are obvious in some cases, whereas others require clarification and a proper interpretation of the different assessments based on a deeper analysis.

4.4 International Co-operation

In both Delphi surveys *necessity for international co-operation* (or 'joint development' as in the English version of the NISTEP Report) could be evaluated as *high*, which means that worldwide joint development is absolutely necessary for the realization of the given topic, as *medium,* if co-operation is necessary, especially for a better result, as *low* when it is not estimated to be necessary although there is the possibility of co-operation in general, or as unnecessary (*none*). In the calculation of the indices (see chapter 1.5), the answers *high*, *medium* or *low* for each individual topic were taken into account. The "none" answers got a zero weight.

The German questionnaire used the word "weltweit" (worldwide) instead of "international" in the same context in order to clarify that not only the European Union (EU) but also the triad countries are meant. The distance from Germany to other countries is not as far as that of Japan to her neighbours. Co-operation between neighbouring countries which are quite normal within the EU and in particular between the German speaking countries Switzerland, Austria and Germany, is not unambiguous. Some experts did not regard this as real international co-operation, but as European, so that the wording "weltweit" made it theoretically less ambiguous. However, whether the threshold of the assessment of internationalism is applied in the same way in the Japanese and the German surveys, remains an open question. Certainly, most of the experts noticed no difference between the terms, so that no differences in judgement based on this criteria can be expected.

4.4.1 Necessity for International Co-operation on the Micro Level

In the ranking of the averages (for the calculation, see chapter 1.3) of the necessity for international co-operation on the micro level, only the first ten topics can be discussed here. In the Japanese estimations of high necessity to co-operate, nearly the same assumptions were made as on the German side.

Table 4.4-1: Ranking of high necessity for international co-operation in the Japanese Delphi survey by single topics (Top Ten)

Two of the ten questions are from the area of Environment, from Urbanization and Construction, from Space and Life Sciences each, and one from Production and from Marine Science and Earth Science. The innovation phase of the topic did not influence the estimation, the topics concern all development phases.

The reasons for a high estimation of the necessity to co-operate internationally are obvious. Most topics already ask for international developments or measurements on a worldwide scale so that it is not surprising if international co-operation is assessed to be absolutely necessary. This can be stated for the *completion of an internationally unified standard for environmental information* (J 9-31/ G 8-31), *international monitoring systems for changes in the atmospheric composition of the stratosphere* (J 6-41/ G 5-41), the *progress in the development of technologies for the worldwide implementation of global environmental preservation measures* (J 11-30/ G 10-30) and the *worldwide reduction of the emission of carbon dioxide* (J 9-12/ G 8-12).

The second type of topic with a high evaluation of the necessity for international co-operation in the Japanese Delphi survey is concerned with space research, e.g. rank no. 1, the *construction of manned laboratories on Mars* (J 12-14/ G 11-14), others like *facilities by which ordinary citizens can stay in space for an extended period of time* (J 12-13/ G 11-13), *a permanent manned space observation base on the lunar surface* (J 4-5/ G 13-5), *landing and return of Mars manned spacecraft* (J 4-4/ G 13-4) as well as topics on *satellites* (J 9-31/ G 8-31) which are, of course, also an international affair. Space is not only "international territory", the related topics are also very cost-intensive. Many projects need international funding as well as international knowledge. Not many countries will be able to continue to finance space research the same extent as before. In the case of space projects, the topics get also a very high assessment in the German Delphi (sometimes even higher than the Japanese) because space research is not performed solely, like it is in Japan by the National Space Development Agency of Japan (NASDA) but is co-ordinated and financed on the European level by the European Space Agency (ESA).

The third type of topic which is seen as relying on international co-operation deals with environmental questions. Because climate, weather and pollution do not stop at a national border, the nations are dependent on each other and one country alone cannot finance large projects on climate research. Topics of this kind would be *standards for environmental informations* (J 9-31/ G 8-31), *international monitoring systems* (J 6-41/ G 5-41), *implementation of global environmental preservation measures* (J 11-30/ G 10-30), and the *reduction of carbon dioxide emission* (J 9-12/ G 8-12).

The fourth type of topic is on biological research such as the *completion of a comprehensive human protein data library* (J/G 3-6) or the *determination of the entire DNA base sequences in human chormosomes* (J/G 3-7). These topics need international co-operation because of their complexity and high costs. Thus, the last mentioned (J/G 3-7) is also included in the list of the German Top Ten (see Table 4.4-2). The German estimations of international co-operation for these ten topics are about the same as the Japanese and in some cases even higher.

The German ranking of the ten topics with the highest estimation of international co-operation (eight of them with an estimation of 100 index points) show a slightly different pattern from the Japanese and the corresponding Japanese judgements are lower in some cases.

Three of the ten topics are from the technological area of Space, two from Urbanization and Construction, two from Transportation and one each from Marine and Earth Sciences, Agriculture, Forestry and Fisheries and Life Sciences.

In the German Delphi, most questions concern co-operation in space research, three of them from the technological field of Space (J 4-4/ G 13-4 *landing and return of Mars manned spacecraft*, J 4-7/ G 13-7 *erection of manned laboratory facility on Mars* and J 4-27/ G 13-27 *practical use of lunar materials as natural resources*) but an additional three also deal with space in general, e.g. J 6-2/ G 5-2, J 12-14/ G 11-14 (which is almost the same as topic J 4-7/ G 13-7) and J/G 14-50. The reasons for the high evaluation of the necessity to co-operate internationally in the area of Space (high costs and funding) have already been given.

Table 4.4-2: Ranking of high necessity for international co-operation in the German Delphi survey by single topics (Top Ten)

In the German Top Ten, only three questions are represented which already implement international approaches, J 6-2/ G 5-2 (*global system for detecting sea surface variability*), J/G 14-41 (*weather forecasts for about 10 days on a global scale*) and J/G 14-50 (*worldwide air traffic control system*) and are therefore judged to rely on international co-operation.

The *determination of the entire DNA base sequence in human chromosomes* (J/G 3-7) is included in the German and the Japanese list. Due to the large number of chromosomes and, therefore, possible sequences, it is a very difficult and time-consuming task, which can only be realized in co-operation on an international level in order to obtain the necessary funding (see above).

There is only one question about weather forecasts in the German Top Ten (J/G 14-41) and none concerning climate and environmental pollution as in the Japanese list. Although it should be pointed out that those topics were given even a higher evaluation in the German Delphi but do not appear in the German list.

The major differences in the German Top Ten list compared with the Japanese results are found in topics no. J 10-61/ G 9-61, J 12-58/ G 11-58 and J 4-27/ G 13-27. The first of them, *the development of production regulation systems as a step toward management of resources and fisheries once it becomes possible to predict the long-term changes in major fishery resources,* is regarded as a global problem which has to be solved co-operatively, especially due to the fact that Germany has not such a large access to the sea as Japan. Japan, as an island, is dependent on fisheries and has no "direct" neighbours like Germany, so that the impression may be given that Japan is independent from other countries regarding the management of resources and fisheries. Nevertheless, the Japanese estimation is medium (index 73), the discrepancy results from the high estimation (index 100) in the German Delphi.

The reason for the difference in the reliance on international co-operation for topic J 12-58/ G 11-58, the *establishment of nation-wide networks for detecting earthquakes, enabling dissemination of disaster preventing systems which transmit information on earthquakes at distances of about 50 km or more in advance,* is quite obvious. In Germany, earthquakes are very rare and there are no strong earthquakes at all, so that research in this field is dependent on co-operation with a country in which earthquakes occur. The networks which are supposed to be established are described as *nation-wide*. Therefore, the Japanese estimated that it is necessary to co-operate on a national but not international level and rated this topic not as high. In contrast, Germany is in the centre of Europe and a distance of 50 km may often involve cross-border problems in the minds of her scientists and citizens. If an earthquake occurs somewhere in Europe, every country is concerned because of the smaller distances involved, whereas Japan has no continental borders.

Another large difference in the judgement on international co-operation can be seen in topic J 4-27/ G 13-27, the use of *lunar materials*. As this is a question concerning space, the reason for the high estimation in Germany is clear: it is cost-intensive, but this does not seem to prevent Japanese experts considering a realization without international co-operation as in many projects concerning space which are conducted by the NASDA. Nevertheless, the Japanese estimation of the necessity to co-operate is still relatively high.

The assessment of the necessity of international co-operation in the German Delphi shows the pattern which had been expected: topics explicitly asking for international approaches are judged with a high index and topics dealing with space are - because of the high costs involved - also evaluated as dependent on international co-operation. German space science and technology is already organized and determined on a European level. Others concern joint approaches to save the environment or deal with climatic problems which have to be solved on a global scale.

4.4.2 Ranking of the Major Differences in International Co-operation

In the Top Ten, the major differences in the evaluation of the necessity for international co-operation are due to high judgements of the German side and lower judgements of the Japanese. There is no example in which the Japanese estimate the necessity to co-operate higher than the German experts.

Table 4.4-3: Ranking of the major differences in the necessity for international co-operation by single topics (Top Ten)

Topics with the largest difference in the judgement on international co-operation are from the technological fields of Urbanization and Construction (three questions), Information and Electronics (two questions) and one topic from Transportation, Mineral and Water Resources, Particles, Materials and Processing and Communications.

The highest difference of 61 index points is calculated for a *marine traffic control system* (J/G 14-38). For Japan, it is easy to establish such a system (if technically possible) without the aid of other nations because it is an island and does not have to co-ordinate such an installation with other nations concerning its shores. Germany only has access to the Baltic Sea and the North Sea, but does not have sole control of these areas and has to co-ordinate control systems with other nations like Poland, Denmark, The Netherlands, Great Britain, France etc. Thus, the necessity for co-operation in R&D is much higher than in the case of Japan.

The same can be said about rank no. 2, the *establishment of comprehensive, wide-area water control and management technology for rivers, dams, and other water resources in the vicinity of major cities, enabling a more effective use of water resources* (J 12-3/ G 11-3) and the *recycling of waste water* (J 7-25/ G 6-25). Japan as an island "in splendid isolation" is only responsible for its own rivers and water resources. They do not have to be shared with other nations, but in the case of Germany (or other European nations), the rivers pass through different countries, so that the regulation of a river in one country has an impact on other nations, too. Indeed, many larger rivers form the national border between countries. Thus, concerning water control over a wide area, co-operation has a much higher importance in Germany than in Japan.

The difference in the three topics on computer and related technology (J/G 2-3, J 5-72/ G 4-26, J/G 1-20, J/G 2-4) is similarly obvious. After the US, Japan is the leading country in computer technology (high self-estimation on the R&D level in the Delphi survey for J/G 2-3 and 2-4, Japan advanced or equivalent in J 5-72/ G 4-26 judged by the Japanese and German experts) and has large computer programmes to develop various kinds of related technology independently (see, e.g. Science and Technology Agency, 1993), so the necessity to co-operate with other nations is not regarded as high. For this reason, large companies fear the competition of other country's enterprises if co-operation is too intensive. Contrary to that, Germany does in some of those areas not belong to the leading nations (see judgement on the R&D level). For her, it is becoming increasingly expensive to develop new devices and close the gap to other nations. One possibility of gaining knowledge in this field is co-operation with competent partners. Therefore, German experts judge the necessity for co-operation as relatively high. This may also be the reason for the high discrepancy in the estimation of topic J 13-8 / G 12-8 which has additionally something to do with space transmission, again an area of necessarily international research in the German estimation.

Topic J 12-5/ G 11-5 on the *promotion of distribution of job functions by dramatic progress in information communication and transportation systems* is evaluated differently because the exchange of workers between Japan and other countries is relatively rare. Thus, the promotion concerns mainly jobs inside Japan, for which international co-operation has no importance. In contrast, Germany already participates in international (European) co-operation with frequent exchanges of R&D staff and salesmen. There are, for example, commuters who live in one country and work in another. For those persons, the co-operation and co-ordination of information communication and transportation systems is essential on an international level.

Topic number J 12-58/ G 11-58 was discussed in chapter 4.4.1.

Summarising the results of the Japanese - German comparison on the necessity of international co-operation, the differences are mainly due to specific cultural or geographical reasons (the conditions of Japan as an island are different from those of Germany in the centre of a continent) which influence the judgements of the experts. Others result from the fact that one country (e.g. Japan in computer technology) is superior in one technological area and therefore the experts of this country see no reason to rely on co-operation and thus, neglect the necessity of international co-operation.

4.5 Time Variance of the Forecast Compared with Certainty

As already described in chapter 2.4, the *accuracy* of forecasting methods can only be determined retrospectively and *precision* is a measure of how exactly the result is determined without reference to any "true" value. The precision of forecast data can be determined. A useful way of representing various degrees of precision is by calculating quartile and median values and representing them graphically (for instance with respect to the time of realization as in the Japanese and German Delphi reports for each topic). The interpretation of "broad" and "narrow" distributions of estimates is, however, not straightforward. In the case, where every expert makes a similar forecast, the distribution will be narrow. If there are two or more schools of thought among the experts who disagree in the timing of future events, we will observe a broad band of opinions, although the precision of time determination is good. In order to separate the real precision assessment from disagreement factors among experts, the experts were asked directly to answer the question of their "Certainty" of this estimation. For the interpretation and calculation of the "Degree of Certainty", see chapter 2.4.

This difference between *time variance* and *certainty* has to be kept in mind when comparing the different types of precision of the Delphi forecast (for the calculation see chapter 1.5). In this chapter, a ranking of the ten highest discrepancies between the upper and lower quartile of the time of realization is presented (ranking of the time variance), which covers the diverging estimations of 50 per cent of the experts of the time of realization. The smaller the time variance is, the "better" the consensus or, the other way round, the higher the topics rank in the following lists, the greater the lack of consensus or general uncertainty about the realization of the specific topic. The latter can be checked by comparing the variance with the estimated certainty (average index value for the whole survey was 38 in Germany and 37 in Japan) of the statement.

Most of the ten topics with a broad time variance in the Japanese estimation have a late realization time in general (upper quartile later than 2020), only topics J 11-14/ G 10-14 and J 11-61/ G 10-61 show a more medium time of realization underlining the fact that the later the predicted time of realization, the greater the uncertainty

Table 4.5-1: Ranking of the largest time variances and comparison with the certainty of topics in the Japanese Delphi survey (Top Ten) and the broader the time variance. The width of the time variance is, therefore, due to a general uncertainty on the matter in the distant future.

The topics with the broadest variance in time are in the innovation phase of Practical Use or Development, none of them in the stages of Elucidation or Widespread Use. Three are from the technological area of Mineral and Water Resources and from Production and two each from Agriculture, Forestry and Fisheries and Transportation. All topics are evaluated with a certainty below the average of 37 by the Japanese.

The highest variance in time is 17 years for new *reduction methods in aluminium smelting* (J 7-3/ G 6-3) with a similar variance in the German estimation (15 years) and a relatively low certainty in the Japanese survey (index 19) which might be the reason for the width. The German estimation of certainty is higher (index 50) high enough to assume a general lack of consensus. The experts in Japan seem to be undecided about the realization of these methods whereas in the German survey, different opinions on the realization time must be noticed. Unfortunately, only a few experts answered this topic in Germany so that perhaps, the result is spurious.

The second topic, *technologies for producing proteins from carbon dioxide and ammonia by bioreactors* (J 11-14/ G 10-14) shows a three years broader time variance in Japan with a similar below average certainty as in the German Delphi (index 32 in Japan and 23 in Germany). This again may represent a general uncertainty and cannot be explained by different attitudes towards the topic in both countries.

The next five topics (J 7-1/ G 6-1, J 11-61/ G 10-61, J 10-52/ G 9-52, J 7-20/ G 6-20 and J/G 14-26), although totally different in their content, show the same pattern of difference. In these topics, the time variance is 5 or 6 years less in the German survey than in the Japanese with a low or medium certainty. The time of realization in the German Delphi survey is also estimated earlier than in the Japanese. As the variance increases with time (i. e. the more distant the future, the greater the variance, compare chapter 3.5), this may be the explanation for the discrepancy and has nothing to do with a different cultural background of the questions. However, the different determination of the realization time by the two groups of experts is a serious deviation, the background of which should be clarified in each of the five cases.

The time variance of the last three topics of the Japanese Top Ten (J/G 14-30, J 10-56/ G 9-56 and J 11-36/ G 10-36) is evaluated similarly in both countries. All topics have a late realization time and a certainty below average. The only exception is no. J 11-36/ G 10-36 with an earlier realization time in the German Delphi and, maybe as a result, a smaller time variance. The assessment of certainty in this question is low in Germany but still below average in Japan.

The pattern of the German Top Ten in the variance of time is totally different from that of the Japanese. In general, the top time variances are broader than in the Japanese Delphi and most of them concern Widespread Use, although there is also one each from the technology phases of Elucidation, Development and Practical Use. The general explanation can be offered that one of the problems is to determine when the phase Practical Use ends and the Widespread Use of a certain technology can be said to have begun, so that a general ambiguity may result from this fact, as well as from a lack of consensus.

Four of the German Top Ten are from the technological area of Marine Science and Earth Science, two from Mineral and Water Resources and one each from Agriculture, Forestry and Fisheries, Materials and Processing, Culture and Lifestyles and Environment.

The first rank has a time variance of 24 years, the estimations are made with a relatively high certainty of index 50 (average index 38), whereas the Japanese experts judge a lower certainty of index 39 (but still above the Japanese average of index 37) but a smaller variance of time (8 years). As the realization is expected relatively late in Germany, a broader variety than in Japan is to be expected, where an earlier realization time is predicted. This seems to make sense, but astonishingly, the second round of the German survey was answered in a completely different way from the first. In the first German round, the time variance was relatively small, even smaller than the Japanese, and an early time realization was expected. This cannot be explained by the Delphi data alone, perhaps something happened in the time between the first and second round (e.g., a press release on the topic) that made

Table 4.5-2: Ranking of the largest time variances and comparison with the certainty of topics in the German Delphi survey (Top Ten) the (few) German respondents change their minds. Despite this, they made statements that their knowledge of the future is very precise. Further investigations would be necessary to explain this difference.

The second topic with a broad time variance in Germany (22 years) also coincides with a high certainty of the estimation (index 59). The Japanese experts do not display such a broad variance (12 years), but do claim very high precision in their judgements (index 64). In both cases, the realization is expected before 2016. The difference is as difficult to explain as in the previous question. One possible explanation may be the unspecified determination of the content (When does Widespread Use start concerning levees? What do "better" levees mean, as the question was formulated in the German Delphi, or "super" levees, as formulated in the Japanese survey?), but this cannot explain such a large discrepancy.

The next two topics on *forecasting outbreak and scale of pyroclastic flows* (J 6-77/ G 5-77) and the application of *ultra-sonic estimation fish sonar and remote sensing* (J 10-55/ G 9-55) are both predicted to be realizable before 2020 but with a 13 and 12 years broader time variance in the German survey, respectively. The certainty is around average or above in both cases, but both concern topics which are not as relevant in Germany as in Japan (Germany has no active volcanoes and its fishing industry is disappearing), so that the broader variance in Germany represents less precision.

The topic concerning *mass production of new materials made by using ions and particle beams with controlled characteristics* (J/G 1-88) is estimated with a broad time variance and a generally late forecast on the realization time by the German experts because of uncertainty (index 25). The precision on this theme seems to be higher in Japan, where an earlier realization is expected and the certainty is higher (index 37). The idea of using accelerators, i.e. large research facilities for mass production probably sounds futuristic in Germany.

The expectation of the *inauguration of experiments in which the extrusion of magma from underground is induced or suppressed in volcanic areas* (J 6-79/ G 5-79) does not differ as much from the Japanese forecast in the German prediction as in the other questions, although the time variance is 5 years broader in Germany than in Japan. The topics are, however, not assumed to be realized before 2020. The certainty of the estimation is slightly below average in Germany (index 33) and low in Japan (index 24). It has to be kept in mind that expertise on volcanoes is limited in Germany which might be the reason for the discord in the estimation.

The next two questions (J/G 16-11 and J 6-58/ G 5-58) seem to show the same pattern of estimation. In the German survey, both have a broad time variance of 18 years and a relatively high degree of certainty whereas, in Japan, the time variance is only 7 years with about average certainty. There, the realizations are expected earlier regarding the upper quartile of the forecast, but this is not a sufficient explanation of the time variance. One reason might be a discord on the interpretation of Widespread Use or, in J/G 16-11, the ambiguity of "better-tasting drinking water", which is a highly subjective question to do with the preferences of the individual and neither the taste itself nor the threshold level of "bad-tasting water" can be objectively measured.

Topic J 6-35/ G 5-35 on the *widespread use of technologies for utilizing deep-layer water* does not show any consensus in Germany, either. Some German experts believe that it cannot be realized before 2020 with a certainty of index 18 that is below average. This demonstrates that the German experts do not seem very sure about their estimation and this is underlined by the fact that most of the respondents do not consider themselves as having a high degree of expertise on this matter. Their Japanese colleagues show less discord (9 years), more expertise and estimate the realization earlier (upper quartile before 2013) with a slightly higher degree of certainty (index 35).

The last topic of this ranking concerns the *elucidation of impacts exerted by destroying tropical forests upon the ecosystem* (J 9-27/ G 8-27). Although the certainty of the German experts for this topic is around average, the time variance is very broad (18 years). The realization is not expected before 2020 (upper quartile). The Japanese expect it to be realized earlier and display less discord, but the time variance of 11 years is still broad. The certainty of the Japanese experts is also somewhat below average (index 32). In this topic, there are perhaps different opinions involved which cause the broad variance by creating dissent between those persons who expect an early and those who expect a very late realization because of a general pessimism concerning tropical forests, climate and the future of the Earth in general. This pessimism is widespread in Germany and would explain the broader time variance there.

To conclude, one can assume that the broadest time variances in the Japanese survey are due to the generally late predictions of the realization of the specific topic. The much greater dissent that can be observed in the German survey is more difficult to explain. It was assumed that this would mainly be caused by different scientific schools and their opinions and by those experts who judge more optimistically or more pessimistically according to their way of thinking . However, the analysis of the first ranked ten topics shows that no such easy conclusion can be drawn, but that different interpretations of widespread use, the comprehension of certain terms and differences in certainty of estimations are more likely to be the reasons for discrepancies in the time variance.

4.6 Most Efficient Innovation Projects

Identifying the most efficient innovation projects from the Delphi questionnaire is not an easy task. Most of all, an operational definition of *efficiency* is required. In economics and the management sciences, the measurement of efficiency is generally associated with an input-output concept. The higher the output and the lower the input, the more efficient an economic transaction is considered. However, we do not know the inputs and outputs of the innovation projects beyond the single topics of the Delphi survey, as these were not part of the investigation. On the other hand, we may assume, that the more important topics are related to an expected above average output. The Delphi respondents were asked to consider the following when assessing the importance of an item: the impact of the innovation projects on the progress of science and technology *or* on the economy *or* on the society. Therefore, it is justified to equate a higher importance level with higher outputs in the case of a successful development or practical use of the issue in question. The outputs relate either to the further returns of research and development or the economy or society.

On the input side, detailed information on the various constraints is available. It is obvious to assume that larger constraints will require greater inputs in terms of money, knowledge, personnel, legislation and so on. Therefore, it can be assumed that the constraints correlate in a certain way with the input necessary to surmount them. If we relate low constraints with high importance for the individual topics we have a sort of input-output concept and may calculate efficiency from this. Efficient topics would be those for which high importance levels coincide with few and low constraints. Efficient innovation themes are not necessarily those with top importance ratings but rather those with favourable relations of high levels of importance associated with low levels of inputs, i.e. problems to be solved must be put in perspective.

As we do not deal with monetary figures in the Delphi survey as in economics, the usual productivity relations cannot be applied here. The approach we have adopted is borrowed from the management sciences, in which efficiency measurement tends to be regarded as a problem of linear programming and optimisation. Admittedly, in the management sciences, practically all analyses of this kind relate to purely monetary parameters, which, in the present circumstances, are inapplicable. But there is a version of linear programming which expressly accepts other non-monetary parameters and also, in this case, provides an efficiency measurement for any so-called "decision-making units" (such as production establishments, companies or branches of industry). This approach, devised in 1978 by Charnes and Cooper, is known as the "Data Envelopment Analysis (DEA)." Essentially, the DEA method investigates which of the "decision-making units (DMUs)" are at peak productivity and which are not. In this case, the peak is defined in multi-dimensional space by the envelope containing all the efficient DMUs, i.e. the corresponding iso-line.

In the present case, the DMUs are defined by the topics in the Japanese and German Delphi questionnaire, which, due to external factors and also science-indigenous reasons, display a certain importance to constraints pattern. Efficiency is considered to be achieved if the scientific and technological community within a specialist area attains a maximum output, i.e. importance per standard input, i.e. efforts to overcome the constraints. The use of the DEA method in the field of science and technology research has already been discussed in detail by Grupp et al. (1994) and the relevant mathematics will not be repeated in this report.

The DEA method allows one or several input factors to be handled independently of each other. In this analysis, we could select any of the constraint factors which would make the analysis quite complex. In fact, if we consider the results of chapter 2.7, most problems lie in the technical and cost factors. The other constraints are less frequently mentioned and generally lower in terms of percentages. Therefore, these two input factors were taken for the analysis, one for measuring the inputs in R&D which are required and the other measuring the costs to bring about the innovation. In the following, the most efficient topics per area, according to the German and Japanese evaluation, are discussed. It should always be borne in mind that an innovation item could be efficient, if it is associated either with high importance and medium constraints or with a moderate importance level and very low inputs required to overcome the technical and cost problems.

Applying this optimisation method, 45 Japanese and 52 German questions were filtered out as the most efficient. For both countries, the most efficient averages of importance are higher than the general ones (Importance index in the Japanese survey - overall index: 65, efficient questions: 77; Germany survey- overall: 59, efficient questions: 65), while the averages of the constraints are lower than the general average (technical constraints in the Japanese survey overall: 68%, efficient: 53%, cost constraints overall: 36%, efficient: 15%; technical constraints in the German survey overall. 49%, efficient: 29%, cost constraints overall: 33%, efficient: 17%).

In spite of the similarities that could often be seen between the German and Japanese evaluations, only 12 questions were considered as being able to be solved effectively in both countries, with a maximum of one per technological area. Different tendencies are visible in the distribution of innovation phases throughout the selection. In comparison to the distribution of the phases in all 1146 questions (Elucidation: 11%, Development: 29%, Practical Use: 39%, Widespread Use: 21%), the Japanese selection of effective questions exhibits a tendency towards the *earlier* phases (Elucidation: 27%, Development: 27%, Practical Use: 30% Widespread Use: 16%), while the German selection has an orientation towards the *later* phases (Elucidation: 12%, Development: 17%, Practical Use: 42%, Widespread Use: 29%).

In the following discussion of selected questions, the impacts of all constraints on the probability of realization have to be discussed, because in a lot of cases, technical and cost problems are overruled by problems on the level of regulations, culture, funding, human resources or the R&D system available. In particular, those questions where one of the constraints, in most cases the cost constraint, is zero are, per definition, at the borderline of efficiency, even if the other constraints were given a rather high ranking or the importance is low. For reasons of clarity, the discussion of efficient topics follows the order of the 16 technology areas.

4.6.1 Materials and Processing

In the area of Materials and Processing, four questions of the German Delphi (J/G 1-42; J/G 1-53; J/G 1-54; J/G 1-104) and three of the Japanese (J/G 1-38; J/G 1-53; J/G 1-97) were rated as efficient. Only question J/G 1-53, asking for the *development of self-healing high polymers imitating animal skin,* is efficient in both countries. The efficiency is induced by clearly below average evaluations of the cost constraint, which in Germany is 0 (average: 30%, the average here and in the following refers to the average evaluation the indicator was given in the specific area of technology) and in Japan 6 per cent (average: 30%), but there is a high rating for technical constraints. The underlying reasons for this evaluation are problems in modelling the very complex molecules of polymers on the one hand and rather inexpensive ways of production on the other. A different evaluation is given concerning institutional constraints, which are rather high for Germany (27%) and, with an evaluation of 2 per cent, low for Japan. The reason for this assessment is to be found in the experiments with animals which would be necessary for the development of such polymers. German society and, consequently, the regulations are highly sensitive to this topic, which would probably hinder the development.

Question J/G 1-38 (*development of superconductive materials with a transition temperature around room temperature),* which was determined as efficient for Japan, exhibits a similar structure as J/G 1-53 concerning the constraints. With regard to other constraints, a high value for funding problems can be found, which, together with the technical constraints, probably results in the late time of realization (2017), in spite of the high importance (90 index points) given to this topic. The third question that was evaluated as efficient for Japan, J/G 1-97 (*practical use of carbon dioxide fixation technology necessary for protecting global environments),* also got a high ranking in the importance index (index 87). While the technical constraints are slightly below average, although still high (82%), cost constraints were given an evaluation far above average (53%). In both countries, only a few respondents of high expertise could be found for this question, so that the efficiency score is less robust.

Question J/G 1-42 (*realization of storage density of 100Gb/cm^2 by the use of Photochemical Hole Burning devices)* from the German selection shows low rankings in both constraints, 42% for the technical ones, 0% for costs which - applying the DEA method - resulted in an efficient rating, in spite of an only average importance. This result is contrary to the Japanese one where both cost and technical constraints were given an above average evaluation. As Japan is considered the leader in this technology, the estimation of higher costs and lower efficiency seems to be more reliable.

Of all the efficient questions calculated for Germany, question J/G 1-54 dealing with the *elucidation of the biocompatibility of materials for living bodies* received the highest evaluation concerning importance together with low rankings for both technical and cost constraints. The high importance can be contributed to the need for biocompatible materials within the area of medicine, especially transplants. With all other constraints being low, the real problem in this case is an insufficient R&D system. In particular, missing links between material science and medicine could be the reason for this evaluation.

Question J/G 1-104, dealing with the *establishment of means for estimation of the residual life of metallic materials using perfect compilation of metal corrosion data bases,* represents another kind of structure of evaluation. Here, importance is average and the few technical constraints are connected with the problem of high costs. Additionally, institutional constraints were given a high ranking. In spite of these hindrances, the time of realization was estimated as early as 1999. The driving force behind this development is probably the branch of mechanical engineering which is quite dominant in Germany and for which metal corrosion is an important issue.

4.6.2 Information and Electronics

In the area of Information and Electronics, three topics from the Japanese Delphi (J 2-64/ G 2-65; J 2-81/ G 2-82; J 2-83/ G 2-84) and two from the German (J 2-77/ G 2-78; J 2-81/ G 2-82) are identified as efficient. Looking at the questions in general, different tendencies are obvious for the two countries. All the Japanese questions have an importance above the area's average. In two cases, high technical constraints are compensated by very low costs. Both German questions show an importance below average together with few constraints. For both countries, at least one question concerning security and one dealing with software and artificial intelligence were considered effective. Whereas the latter are not realized before 2020, the former have an estimated time of realization around 2006. Question J 2-

81/ G 2-82 on the *elucidation of brain mechanisms in human decision making*

which is efficient in both countries, was already discussed in chapter 4.2.2, and therefore, shall not be considered further.

Question J 2-64/ G 2-65, asking for the *widespread installation of sophisticated equipment designed to prevent crimes*, received an average importance rating in the Japanese selection. Although costs are estimated above average, the real problems have to be sought at the institutional as well as the cultural level (e.g. data protection or acceptance).

The third efficient question of the Japanese selection deals with the *elucidation of human creative mechanisms to such an extent that allows their application to computer science* (J 2-83/ G 2-84). While costs are below average in this case, technical problems hinder the development in addition to deficits in human resources. It can be assumed that the difficulty of the necessary interdisciplinary approach (biologist to explain human creative mechanisms and computer or electronic specialists) is regarded as the major problem hampering the realization.

The second German efficient question asked for the *widespread use of general purpose ID card systems capable of decoding, with no contact, almost all information socially requisite for individuals* (J 2-77/ G 2-78). The importance of such a development is rated rather low at 42 index points. As specific ID cards are already in use for a lot of purposes in Germany technical (5%) as well as cost (2%) constraints are nearly non-existent. High values for institutional as well as cultural problems are in contrast with this low evaluation. The discussion about the security of personal data has been one of the most sensitive topics in Germany over the last few years. The German culture is rather individualistic and tends to be worried about the "Big Brother" society, which watches every single step as described in Orwell's novel "1984", so a device storing all important personal data has only a low social acceptance. In addition, strict regulations safeguarding the integrity of personal data form a strong barrier to the development of such a general system.

4.6.3 Life Sciences

In the area of Life Sciences, four questions from the Japanese (J/G 3-7; J/G 3-11; J/G 3-21, J/G 3-64) and three from the German (J/G 3-48; J/G 3-55; J/G 3-97) Delphi turned out to be efficient, with no equivalencies in this case.

Two topics from the Japanese selection have already been discussed in preceding chapters (J/G 3-7 in 4.4.1; J/G 3-11 in 4.2.1) and will, therefore, not be handled further. Question J/G 3-21 asked for the *elucidation of functions of immunocytes responsible for the distinguishment between self and not-self*. While the efficiency of this question is due to the extremely low rating of cost constraints the real problems for realization are insufficient funding (38%) and deficits in the human capital available (45%). This reflects the assumed lack of personnel in the biology sector dealing with gene research. The same pattern of answers can be seen in question J/ G 3-64, which deals with the *elucidation of the functions of homeobox genes in a vertebrae.*

The topics from the German selection present a similar picture concerning the low rating of cost constraints, while technical constraints and importance give a mixed impression. Question J/G 3-48 deals with the *long-term culture and preservation of organs*. With an importance of 78 index points, it is ranked high. Organ transplants is an important branch of medicine in Germany and Europe in general. Apart from finding the right organ to implant, the most important problem in this area is the storage of good material over a longer time. Technical as well as institutional constraints which are over average seem to hinder an early development (2007).

Question J/G 3-55 from the German efficient selection deals with the *elucidation of the elasticity of neural networks in interaction with the environment.* This question, which is about average in importance, has low valuations for both technical as well as cost constraints. The main hindrance for an early and easy realization of this technology seems to be an inefficient R&D system.

Also of interest is question J/G 3-97 which deals with the *elucidation of the behaviour of microorganisms in the biosystem and practical use of genetically engineered microorganisms released into environments.* With an importance slightly above average and low estimations for technical as well as cost constraints, it is estimated to be realised as soon as 1999. Not visible from this evaluation are the enormous institutional (73%) and cultural (35%) problems imposed on this issue. While theoretical research in the area of genetic engineering is quite successful in Germany (constraints from the R&D system are 13%), the discussions among certain sectors of the public are strongly influenced by the fear of man-made monsters. Due to these fears and the need to control a highly sensitive kind of research, the regulations in this area, especially concerning the release into the environment, are extremely strict.

4.6.4 Particles

Within the area of Particles, three German (J 5-64/ G 4-18; J 5-81/ G 4-35; J 5-85/ G 4-39) and two Japanese (J 5-67/ G 4-21; J 5-81/ G 4-35) questions were rated as efficient. Looking at the importance, both the Japanese and the German questions show a similar pattern, all being far above average in this technological area. No clear tendencies can be seen for the constraints. The topic chosen by both countries, J 5-81/ G 4-35, has already been discussed in chapter 4.2.1.

The second topic from the Japanese selection, J 5-67/ G 4-21 (*widespread use of subminiature proton and heavy iron accelerators for medical treatment and diagnosis of deep-body cancers*) is, apart from having a high importance index of 81 also characterised by above average cost constraints but comparatively low technical hindrances (60%). The importance of this topic derives clearly from the eminent danger of cancer. Costs are high in this case because accelerators are not yet in serial production, on the other hand, a lot of research has already been done on the subject of beam therapies for cancer making the technical problems seem less extreme.

Within the German selection, question J 5-64/ G 4-18 is of special interest, which deals with the *development of quenching processing and nuclear transmutation technology for radioactive waste by high-energy elementary particles*. As Germany has problems in finding sites for radioactive waste, the above average ranking for importance is easy to explain (82 index points). With 50 per cent technical constraints, it has still the lowest rank. Not only cost constraints are above average, institutional and cultural problems also hinder the realization. In Germany, a strong opposition to nuclear energy exists which tends to foster the total neglect of this area of research rather than "healing the symptoms", e.g. waste. Additionally, handling with nuclear materials, even for experimental purposes, is subject to strict security regulations making it rather time consuming to do research in this area.

The last question from the German selection (J 5-85/ G 4-39: *practical use of equipment capable of real-time X-ray structure analysis for large bio-macromolecular crystals*) is high in importance (86 index points) and technical constraints (86%). Cost constraints are zero but rather high deficits in funding have to be considered instead.

4.6.5 Marine Science and Earth Science

From the area of Marine Science and Earth Science, one Japanese (J 6-81/ G 5-81) and three German topics (J 6-22/ G 5-22; J 6-49/ G 5-49; J 6-81/ G 5-81) were evaluated as efficient. In all cases, the technical constraints are below average, while importance as well as cost constraints show no clear tendency.

For both countries, question J 6-81/ G 5-81 (*Inauguration of global science and technology education organisation in the broad sense for fostering international scientists and technologists contributing to conservation of global environment, development and maintenance of global resources*) was regarded as efficient. In both cases, the evaluation of importance was high (J: 88, G: 71). The United Nations conference in Rio de Janeiro made it especially obvious that environmental protection and preservation is an issue to be dealt with on an international level, as the damage cause and the damage itself are often distributed over several countries. The difference in the evaluation of importance might be found in the already strong involvement of German researchers in environmental topics, and therefore, a less pronounced need to co-operate. Whereas, in Germany, there is no problem in finding researchers and their education is regarded as sufficient, Japan still has to foster the development of a research infrastructure for environmental issues as the constraint of missing human resources and of the R&D system at is rated 44 per cent and 30 per cent respectively, both far above the average. Apart from the difference in importance, several other constraints are also rated dissimilarly. The German respondents see most of the problems in financing such an organisation (46%), while the Japanese see the cost constraint as a low 5 per cent. The reason for this difference might be an ambiguity in the terms "cost" and "funding", as in the Japanese Delphi funding constraints were rated above average (31%). A similar case may have occurred with the cultural and institutional constraints. While in the German Delphi cultural constrains are rated high (50%) and institutional ones low (7%), the Japanese response seems to be the complete opposite: cultural constraints are low (13%) and institutional ones high (57%). The underlying reason might be the same, as it will be hard to create the organisation (institution) in such a way that people from different countries are able to work in harmony.

The second efficient question from the German selection deals with the *establishment of a comprehensive marine ecosystem theory, enabling elucidation of impacts on the ecosystem arising from marine development* (J 6-22/ G 5-22). For this topic, importance is slightly above average, while both technical (5%) and cost constraints (16%) are far below average. This, again, is one of those questions where the real problems of realization have to be sought in the assessment of other constraints, here represented by deficits in the R&D system (55% - average: 17%). As Germany does not have a big variety of marine territories, this kind of research was neglected in the past, a fact that could also have induced an underestimation of the problems. A comparison with the Japanese answers shows that technical (54%) and funding problems (44%) receive higher ratings, maybe underlining this judgement. The last question from the German selection (J 6-49/ G 5-49) has already been discussed in chapter 4.3.1 and shall not be considered further.

4.6.6 Mineral and Water Resources

In the area of Mineral and Water Resources, three of the Japanese questions (J 7-12/ G 6-12; J 7-36/ G 6-36; J 7-38/ G 6-38) and four of the German (J 7-4/ G 6-4; J

7-13/ G 6-13; J 7-31/ G 6-31; J 7-39/ G 6-39) were rated as efficient. Two German questions and one Japanese are from the section of mineral resources, while the others concern water resources. With regard to importance and constraints, no clear tendency can be perceived in the answers.

The first Japanese question, asking for the *development of new mineral deposits discovered by the exploration based upon new geological theories such as plate tectonics* (J 7-12/ G 6-12), got a slightly below average judgement of importance which is compensated by rather low evaluations for both technical and cost constraints (3% - average: 48%). As Japan does not own mineral resources and, therefore, is less advanced in this kind of research, the real obstacles are deficits in human resources (45% - average: 10%) as well as in the R&D system. In order to build up a strong representation in this area, first, a sufficient infrastructure for research would have to be created which is indicated by the high value for funding constraints. A similar situation is found in the second German question within the area of mineral resources (J 7-13/ G 6-13), dealing with the *development of exploration technology capable of estimating the economic feasibility of mineral deposits with virtually no drilling.*

Of the two Japanese questions dealing with water resources, one (J 7-36/ G 6-36) has already been discussed in chapter 4.3.2. Question J 7-38/ G 6-38 asked for the *quantitative estimation of the influences of acid rain on the water system, allowing corrective measures to be formulated*. For this question, both importance and technical constraints are judged as being slightly higher than the technological area's average. The low costs, which induce the efficiency of this question, have to be measured against the problems on the institutional level and within the R&D system. Until now, Japan was not very active in research on acid rain, which was regarded as a European and American problem but has gradually increased in importance for Japan in recent years.

Topic J 7-4/ G 6-4, which was rated as efficient in the German sample, shall be excluded from further discussion as only four experts with a low degree of expertise answered this question; the DEA analysis is not robust. Question J 7-31/ G 6-31 deals with the *practical use of water purification technologies for rivers, lakes, and marshes spurring environmental improvement and more effective water use* and was judged as the most important in this field of technology in the German selection. While technical constraints are rated below average, particularly high costs and funding constraints will hinder this development, all other constraints being rather low. The reason for the high rating of financial problems might be the perception that a vast number of water purification facilities will have to be adjusted, incurring high costs.

The last question, J 7-39/ G 6-39 (*development of technologies enabling accurate forecast of environmental impacts caused by very small amounts of pollutants*), is also marked by a rather high evaluation of importance. As technical and cost constraints are rather low, the real constraints result from an inefficient research system (58%). As already mentioned above, there seems to be a lack of researchers and institutes in such broad fields of research which are generally dependent on interdisciplinary approaches. This might explain the evaluation of the R&D system as a constraint on the realization.

4.6.7 Energy

In the field of Energy, three topics of the German (J 8-13/ G 7-13; J 8-16/ G 7-16; J 8-28/ G 7-28) and the Japanese (J 8-23/ G 7-23; J 8-28/ G 7-28; J 8-50/ G 7-50) survey are rated as efficient. For both countries, the importance of the questions is above average, while the constraints give a mixed picture.

Two of the Japanese questions concern problems from the section of nuclear power. Question J 8-23/ G 7-23 has already been discussed in chapter 4.3.2. J 8-28/ G 7-28 deals with the *practical use of technology for the safe disposal of highly radioactive solid waste* and is also included in the German sample of efficient questions. The importance index of solving this problem is rated very high in both countries (J: 92, G: 91), as the safe disposal of nuclear waste is a basic necessity for the broad use of nuclear energy. Technical and cost problems were rated below average. The main problems in Germany, as well as in Japan, are of institutional and cultural character. As already discussed for question J 5-64/ G 4-18, a strong opposition to the use of nuclear energy exists in Germany which impedes the solution of the nuclear waste problem in order to hinder the use of this kind of

energy.
The third of the efficient Japanese topics deals with the *establishment of the concept of a thermal industrial complex aimed at total, efficient use of energy* (J 8-50/ G 7-50). While technical constraints are judged below average (32%), cost (69%) together with institutional (52%) constraints seem to be the main hindrances to finding a solution. In the German survey, most experts claim technical and cost constraints as the major obstacles to realization and criticise the assumption that a totally efficient use of energy is asked for which is contrary to the laws of thermodynamics (see chapter 1.4). Why the Japanese regulations hamper the realization has to be clarified by further investigations.

The two other questions rated efficient in the German sample deal with renewable energy: *widespread world-wide production of energy using biomass as raw material* (J 8-13/ G 7-13) and *practical use of innovative passive solar houses which effectively use natural energy* (J 8-16/ G 7-16). Both questions exhibit a similar pattern in the answers: the technical constraints are low, and a rather early time of realization (around 2001) is estimated. Financial problems (67% and 79%) are the main hindrance to the development, institutional constraints (17% and 25%) are also above average and, for the first question, cultural (25%) problems are rather high. Both financial and institutional problems might have their roots in the perceived insufficient support still granted to alternative sources of energy. On the institutional level, the centralisation of the market structure of energy production results in the high value given. The cultural problems linked with the first questions might be due to the word "world-wide", which indicates the need for supra-national agreements.

4.6.8 Environment

In the area of Environment, four of the Japanese (J 9-11/ G 8-11; J 9-29/ G 8-29; J 9-42/ G 8-42; J 9-44/ G 8-44) and three of the Germans (J 9-10/ G 8-10; J 9-42/ G 8-42; J 9-48/ G 8-48) questions were judged as efficient. While in this selection, the importance varies from question to question, both technical and cost constraints are mostly below average. In both surveys, one of the selected questions deals with

global warming. Another accent lies on the section of regional environment.
The first of the Japanese topics asks for the *determination of global warming on the whole world's agricultural production* (J 9-11/ G 8-11). This question is characterised by a high ranking for importance (91 index points). The technical problems are about average (52%) and the costs rather low (8%), the main problem is seen as being insufficiencies within the human capital (41%) and the R&D system (42%). This general lack was already described above.

The second question from the Japanese sample (J 9-29/ G 8-29) has already been discussed in chapter 4.4.1. Question J 9-42/ G 8-42 asks for the *establishment of assessing socio-economic damage because of the destruction of natural environment due to soil conterminations and land subsidence and incorporation of its countermeasure in a regulatory system* and was rated efficient by Japanese as well as German experts. The importance was evaluated similarly in Japan and in Germany and slightly above the area's average. Similarities can also be perceived in technical and financial constraints, which are below average each time. Whereas the Japanese situation is marked by grave problems on the institutional level (65%), in Germany, especially cultural difficulties (45%) as well as insufficiencies in the R&D system (32%) characterise the situation. The high evaluation of institutional problems in Japan might be due to the complications involved in the creation of a national or even supra-national network needed to implement the regulatory system described in the question. The cultural problems seen by the German experts have their root in social disapproval of mankind controlling nature. On the other hand, "countermeasures" may have been understood more as a cure to existing damages instead of their avoidance. This approach may have been given low acceptance in general.

The fourth Japanese question deals with the *determination of presence or absence of trans-generation effects of environmental contamination of human beings* (J 9-44/ G 8-44). For this topic, high importance (index 85) and low costs (3%) compensate for a high evaluation of the technical problems (74%). Apart from this, the values for funding (39%), human resources (34%) and deficits in the R&D system (21%) are also high, indicating a missing R&D infrastructure and the need to create one.

Topic J 9-10/ G 8-10 is from the German selection and asks for the *possibility of an* *approximate forecast of the scale or area affected and damage caused by epidemics due to global warming*. For this question, importance was rated rather low which might be rooted in the fact that, in Germany, dangerous epidemics have nearly disappeared. This fact is also reflected in deficits in the R&D system, as there is not seen to be a need for further investigation.

The other German question which has not yet been discussed deals with the *establishment of an evaluation system for man-made micro-organisms which are created by biotechnology including gene manipulation in open systems, and utilisation of organisms useful for purifying the environment* (J 9-48/ G 8-48). This question received below average rankings for the importance index (62), and technical (17%) as well as cost constraints (6%). As with all questions to do with biotechnological topics, the solution is less influenced by missing knowledge or finances than by cultural (22%) and institutional (47%) factors (see also discussion of question J/G 3-97).

4.6.9 Agriculture, Forestry and Fisheries

For the area of Agriculture, Forestry and Fisheries, three of the Japanese (J 10-1/ G 9-1; J 10-2/ G 9-2; J 10-62/ G 9-62) and one of the German (J 10-2/ G 9-2) questions were determined as efficient. Whereas for the Japanese results, a clear tendency towards above average importance can be seen, the German results are low in technical constraints.

The first question of the Japanese selection J 10-1/ G 9-1 deals with the *elucidation of the base sequences of the DNAs of crops to isolate useful genes*. For this question, the above-average importance index (index 84) is combined with low evaluations for technical (29%) as well as cost constraints (9%). Instead, the need for additional funding (61%) is dominant, together with deficits in human resources (54%) and the R&D system (31%), a combination of problems that indicates the need for an enhanced educational and research infrastructure in this area of technology. For Germany, a similar tendency can be observed but instead of funding constraints, high costs are mentioned in this case resulting in the same conclusion. High costs, or the need for extended funding, are derived from the time consuming task of scanning all the genes for specific DNA combinations.

The second question rated as efficient in Japan can also be found in the German selection. J 10-2/ G 9-2 deals with the *practical use of improved crop varieties created by plant gene manipulation.* In both countries, this question's importance index was rated above average, but with a higher value in Japan (J: 93, G: 78). A reason for the slightly lower estimation in Germany might be the fact that Europe suffers more from agricultural overproduction than having the need to improve crops in order to increase the yield. Different evaluations are given for the constraints. As cost (6%) and technical constraints (49%) are below average in Japan, the stress is on constraints concerning human capital (44%) and deficits in the R&D system (23%) similar to the first question. In Germany, constraints from the R&D system, as well as from education, are rated low with the actual problems seen in institutional (73%) and cultural constraints (33%) which again are due to the rejection of gene manipulation in Germany.

The last Japanese question ponders the *elucidation of the mechanisms of totipotency of plant cells* (J 10-62/ G 9-62). The efficiency of this question is derived from the high importance (87 index points) and low costs (2%) which compensate the high technical constraints (78%). As already stated for the first two questions the real problems have to be sought in the need to develop a suitable R&D and higher education infrastructure for this area of technology (human resources: 42%; R&D system: 25%), a need that results in necessary additional funding (32%).

4.6.10 Production

In the area of Production, three of the Japanese (J 11-19/ G 10-19; J 11-56/ G 10-56; J 11-61/ G 10-61) and four of the German questions (J 11-47/ G 10-47; J 11-57/ G 10-57; J 11-62/ G 10-62; J 11-66/ G 10-66) were evaluated as efficient.

The first of the Japanese questions (J 11-19/ G 10-19) relates to the *development of programmes automatically enhancing functions by learning based on the imitation of biological functions*. In this case, the importance index is slightly above average (index 65) and the costs are rated below average (10%). This compensates for the high evaluation of technical constraints (88%). Besides technical problems, a need concerning an enhanced educational and research infrastructure is indicated by equally high evaluations of funding, human capital and R&D system constraints.

Question J 11-56/ G 10-56 asks for the *widespread use of at-home performance of work in general office divisions* and is in the sample of Japanese efficient questions. All of the three indicators used in the DEA are below average for this question. The main problem involved here is not visible, as there are huge institutional (51%) and cultural (65%) constraints hindering the realization. In Japanese companies, work in face-to-face teams is of high importance, because language (which, by the way, is often ambiguous) is not sufficient for communication. Another factor is that there is often no space for communication and other working equipment in Japanese homes, socialisation with colleagues is difficult and the information flow insufficient. The fourth Japanese question (J 11-61/ G 10-61) has already been discussed in chapter 4.5.

All efficient questions from the German sample show similar pattern concerning such different topics as the *widespread use of sophisticated training systems in career development planning* (J 11-47/ G 10-47), the *widespread use of operatorless systems enabling at-home health examination and diagnosis* (J 11-57/ G 10-57), the *widespread use of factory entertainment where operators and visitors can both enjoy* (J 11-62/ G 10-62), or the *enhancement of individualisation at work, leading to possibility of building individual habits, personalities etc. into software through the use of identity cards* (J 11-66/ G 10-66). Importance, technical and cost constraints (except for costs in one case) are below average in all cases, so the real obstacles have to be sought on an institutional as well as cultural level, e.g. the question concerning career development got a rating of 41 per cent for cultural constraints. The reason for this result may be the difficulties in training older people, especially in technical areas, due to their reduced learning abilities on the one hand, and their fear of confrontation with new technologies on the other. As a second example, J 11-57/ G 10-57 shall be discussed further. Here, the reason for high cultural constraints (43%) can be found in the confidence between physician and patient which can hardly be replaced by an anonymous, self-operating system.

Social acceptance will remain low, as today's physicians often perform the position of a psychological consultant dealing with the personal problems as well.

4.6.11 Urbanization and Construction

For the area of Urbanization and Construction, two Japanese (J 12-2/ G 11-2; J 12-56/ G 11-56) and three German questions (J 12-2/ G 11-2; J 12-22/ G 11-22; J 12-29/ G 11-29) are in the sample of efficient questions. Both Japanese questions are above average in importance and below average in cost constraints, but with no clear tendency for technical constraints. In the German sample, below average evaluations for both constraints can be stated with no tendency in importance.

Topic J 12-2/ G 11-2, concerning the *integration of information on the possessions, utilization, and transaction of land, enabling the use of such information for land policy and city planning,* was rated as efficient in both countries. With 70 index points in Japan and 80 index points in Germany, the importance is above average in every case. As technical and cost constraints are low, the main obstacle is to be sought on the institutional (J: 93%, G: 54%) as well as the cultural (J: 38%, G: 38%) level. Cultural and institutional problems might result from the idea of an active land policy which could result in the dispossession of land owners.

The second of the Japanese questions concerns the *development of disaster forecasting and information transmission systems, incorporation studies in social and behavioural psychology, in order to prevent panic in big cities in event of major earthquakes or fires* (J 12-56/ G 11-56). This question was given above average ratings for the importance index (index 81) as well as for technical constraints (67%), while the expected costs are low (8%). This might be due to the ubiquitous dangers in Japan which are a major threat compared to the costs of disaster prevention. In Germany, the cities are not as big and there are hardly any typhoons, earthquakes and similar disasters, so that such a panic situation would occur only very rarely and is not regarded as such a frequent danger as in Japan.

Question J 12-22/ G 11-22 is the second efficient question in the German sample and asks for the *widespread use of house manufacturing systems directly connected with design support systems*. For this question, all the three indicators used in DEA are evaluated as below average: importance (45 index points), technical problems (10%), and costs (5%). This evaluation does not reveal the main problems which are on a cultural level (48%) as well as in the non-existent educational and research infrastructure (human resources: 38%; R&D system: 24%). This question may have been understood as an approach towards the automation of architecture. In a country where architecture is perceived as a form of art, such a proposal has a low acceptance which is reflected in the respective deficits in human capital and research.

The last of the German questions, J 12-29/ G 11-29, deals with the *construction of cities that present diverse landscapes including roads and bridges due to advances in landscape design technologies*. This question is the one with the highest evaluation of the importance index (index 81) and the lowest for technical constrains (0%) in the German sample of efficient questions. The humanisation of towns and the design of living space has long been an issue of interest in Germany and several approaches have already been realized. The rather high ranking for costs (40%) can be derived from the high costs of construction which are typical not only for Germany.

4.6.12 Communications

From the area of communication, three Japanese topics (J 13-12/ G 12-12; J 13-24/ G 12-24; J 13-38/ G 12-38) and four German ones (J 13-19/ G 12-19; J 13-42/ G 12-42; J 13-44/ G 12-44; J 13-49/ G 12-49) are considered to be efficient. Neither the evaluations of importance, nor the constraints show clear tendencies.

The first of the Japanese questions (J 13-12/ G 12-12) asks for the *development of communication systems applying media other than electromagnetic waves (e.g.,* *neutrinos)*. The importance of this question was rated rather low, as the need for a new means of transmission is not yet perceived and magnetic waves seem to be sufficient even for the next generations of computer. While costs appear rather low (9%), technical problems are above average. An important problem on the technical side may be posed by the lack of knowledge about the neutrinos mentioned as an example. Another reason might be the late time of realization, which does not yet allow conclusions about all the forthcoming problems (see chapter 4.3.2). Therefore, the accuracy of the cost estimation is questionable.

Another topic asks for the *realization of radio telephone numbers, leading to practical use of mobile communication that enables communication with desired parties from anywhere in the world* (J 13-24/ G 12-24). This question is of rather high importance (84 index points) combined with slightly below average evaluations of the technical and cost constraints. The main problems of this development have to be solved on the institutional level, as such a technology needs the creation of a world-wide communication network. In this case, a comparison to the German answers is of interest, where all the indicators described before are valued about 15-20% lower, combined with an earlier time of realization (2002 instead of 2007). As, some networks for mobile telephones are already in use in Germany and new projects are still being fostered, a realization seems more realistic than in Japan.

Question J 13-38/ G 12-38 (*Completion of internationally integrated services digital networks (ISDN) covering virtually all countries, with automatic access from domestic ISDN*) is the third from the Japanese sample. It is marked by a high importance index (index 88), rather low technical problems (22%) and average cost constraints. As in the German response, the main problems are institutional ones (J: 54%, G: 57%) due to the intended global integration which requires the co-operation of a variety of countries. Again, the German answers are more optimistic concerning the time of realization (2001 instead of 2004) of such a communication network.

J 13-19/ G 12-19 is from the German sample and concerns the *practical use of automatic protocol conversion technology enabling easy interconnection of various communications networks.* This question is one of the earliest in realization from this technological area (1997). The importance of such a device is rated very high (index 89) because, in Germany, a variety of different communication networks exist which will have to be interconnected in order to enable improved communication. While costs are low (14%) and technical problems just slightly above average the main constraint is institutional (35%). This evaluation is due to the high regard given to data security in Germany, which will have to be considered in the development of such a technology.

The other three efficient questions from the German sample also deal with problems imposed by communication networks. Although the area of concern is the same, all indicators used in the DEA are evaluated differently, there is only a common tendency towards substantially above average institutional constraints. For question J 13-42/ G 12-42 (*Practical use of telecommunication network with variable algorithms, enabling improvement in the efficiency of network use, durability, and service reliability*), the importance index is evaluated rather high (index 81), technical constraints are about average and costs constraints low. The high importance can be derived from the increased use of telecommunication networks which enforces increased efficiency and security in order to provide sufficient capacity. In topic J 13-44/ G 12-44, dealing with the *junction of house security systems within a regional network, which prevent crime by using highly sensitive sensors*, importance and technical constraints were rated below average, but costs of realization were evaluated as high (55%). Up to now, a system of this scope does not exist and would have to be installed first, resulting in high costs. On the other hand, costs will also be produced after the installation, due to constant use and maintenance.

The last of the German questions, the *realization of high-security communication and practical use of electronic voting by individual identification numbers* (J 13-49/ G 12-49), received low evaluations for all the indicators used in DEA (importance: 22 index points; technical constraints: 4%; cost constraints: 9%). This, again, is a question where the real obstacles are high ratings for both institutional (29%) and cultural constraints (53%). In Germany, a strong mistrust of computer systems is prevalent in parts of society. Concerning the use of computers as a medium in the election process, the fear of misuse is widespread, this is represented by the high evaluation of cultural problems. Institutional problems might be derived from strict regulations and the high security that would have to be applied in such a system.

4.6.13 Space

In the technological area of Space, three of the Japanese questions (J 4-9/ G 13-9; J 4-11/ G 13-11; J 4-44/ G 13-44) and four German ones (J 4-11/ G 13-11; J 4-13/ G 13-13; J 4-26/ G 13-26; J 4-41/ G 13-41) are in the sample of efficient questions. For the Japanese evaluation, a tendency to high assumptions on the importance can be stated, while in the German selection, no pronounced tendency exists.

The first of the Japanese questions (J 4-9/ G 13-9) deals with the *forecast of solar radiation activity to enable astronauts to stay in space for an extended period of time*. At an importance only slightly above average technical constraints (40%) and estimated costs (9%) are rather low. Like in all the Japanese questions of this area, the main constraint is funding (75%), which already received a very high average of 70%. This is a logical consequence of the need for large investments in space research, which are necessary for enabling astronauts to stay in space.

The second question from the Japanese sample, which is also included in the German one has already been discussed in chapter 4.2.1. Question J 4-44/ G 13-44 (*possibility of observing minute space debris that are harmful to space stations and development of technologies for avoiding such dangers*), the third Japanese question was given a high ranking for technical constraints (87%) but low evaluation of costs (10%). A high importance index (index 88) induces the effectiveness. Again, as in the first questions, low costs obscure the fact of an extended need in funding (61%), even though below average in this question.

From the German sample, J 4-11/ G 13-11 has already been discussed in chapter 4.2.1. A question to have a closer look at is J 4-13/ G 13-13 (*application of multi-purpose stationary platforms over the Pacific Ocean for international use*). It got low ratings for both, importance (35 index points) and especially the technical constraints (0%). The main problems are seen in costs (42%) and funding (42%) and institutional constraints are also on a rather high level. The latter might have its roots in the stress that is put on the "international" use, a word that mostly resulted in high institutional restrictions.

Question J 4-26/ G 13-26 deals with the *practical use of isotope batteries for probing deep space*. This question was rated the earliest in the area of Space. While technical (25%) and cost constraints (10%) are considered as low, the principal problem has to be sought on the institutional (45%) and cultural level (25%). A reason for this evaluation might be the need for experimentation with radioactive material, an issue already discussed.

The last question asks for the *development of technologies for full recycling of water and oxygen in space stations* (J 4-41/ G 13-41). The efficiency of this question derives from a high evaluation of the importance index (index 82) and low costs of realization (8%). They compensate a rather high rating for technical constraints (79%) which can be accounted to the use of the word "full" in the question. While recycling technologies are widely used in Germany, a 100%-recycling still remains extremely difficult in the experts' eyes.

4.6.14 Transportation

From the area of Transportation, two of the questions in Japan (J/G 14-40; J/G 14-50) and three in Germany (J/G 14-15; J/G 14-21; J/G 14-50) are evaluated as efficient. Two of these question were already discussed in earlier chapters (J/G 14-21 in chapter 4.3.1 and J/G 14-50 in 4.4.1) and shall therefore not be reflected further on.

Question J/G 14-40, the first in the Japanese selection, deals with the *widespread use of observation systems that provide ships with real-time information on wide-area sea and weather conditions*. This issue is of rather high importance index (index 74) and does not pose a lot of technical problems (28%) as similar, maybe less sophisticated systems have already been installed locally, using radio stations. As with all questions that demand international co-operation, institutional constraints (34%) are an important factor as well as high costs (64%) and funding (32%).

The third of the German questions asks for the *widespread use of motorcars with extremely low fuel consumption owing to reduced weight achieved by introduction of materials such as ceramics etc.* (J/G 14-15). This topic was ranked the most important in the area of Transportation (97 index points) as it is dealing with aspects of fuel and emission reduction, both significant issues in the German environmental discussion. The only major constraints in this development are technological ones (55% - average 39%). As a lot of research is already done on this subject only few additional costs (18%) will result from widespread use.

4.6.15 Medical Care and Health

From the area of Medical Care and Health, three questions in Japan (J/G 15-5; J/G 15-17; J/G 15-25) and five in Germany (J/G 15-18; J/G 15-25; J/G 15-63; J/G 15-96; J/G 15-100) are calculated as efficient. In general, the following tendencies can be observed: the importance of the Japanese questions is above average in all cases, combined with low costs and in two cases, high technical problems. Except for one question the German answers present also a slightly above average importance, the costs and technical constraints being mostly low.

The first of the Japanese topics (J/G 15-5) deals with *Alzheimer's Disease* and has already been discussed in Chapter 4.1. Question J/G 15-17, dealing with the *practical use of methods for securely preventing the later death of neuronal cells*, is the second from the Japanese sample. Technical constraints are regarded as high for this topic (81%), as a breakthrough in cell theory will be needed. This is, again, a question where low costs are obscuring the problem of funding which is necessary in order to enhance the educational and research infrastructure (funding: 45%, human resources: 17%, R&D system: 29%). A similar conclusion can be made for the third Japanese question, which was also rated as efficient in the German sample. Question J/G 15-25 deals with the *widespread use of scientific guidelines concerning lifestyle for prevention of adult diseases, based on advances in nutriology and basic medicine*. Like in the preceeding question, costs are assumed as low, while deficits in funding (29%), human resources (36%) and the R&D system (22%) are rather high for the Japanese answers. As in Germany, a lot of research is done in the area of nutrition, the evaluation of human resources (9%) and the R&D system (9%) are much better. A similar evaluation is given for cultural constraints which are above average in both countries (J: 41%, G: 68%). Already today, a huge variety of guidelines towards a healthier life exists, at least in Germany, which are nonetheless ignored by the broad public. Therefore, an improved acceptance in the future cannot be counted on. For Japan, also institutional constraints are ranked high (32%), but cannot be explained without further information.

The second German question (J/G 15-18) deals with the *development of mental health training techniques, enabling the prevention of mental disorders resulting from stress.* Importance of this question was rated below average (index 54) connected with low evaluations for both technical (12%) as well as cost constraints (4%). As for the first of the German questions discussed, the main problem is one of social acceptance (36%).

Question J/G 15-63 concerns the *development of almost perfectly effective therapeutic drugs for schizophrenia.* Having a slightly above average importance index (index 74) and no cost constraints (0%), technical problems are only insignificantly below average (44%) and the R&D system rather insufficient (39%) ranking on eighth position concerning R&D constraints. This illness is of minor importance in Germany and therefore, the R&D system concentrates on other themes than schizophrenia. In Japan, there is also no stress on this kind of research, the R&D system is rated as inefficient, too, and a lack of investment (42%) is additionally claimed here.

Another question rated as efficient in the German sample (J/G 15-96) deals with the *development of controlling devices which help the co-ordination of object-oriented muscular movements*. While cost problems seem non-existent, technical constraints as well as above average deficits in the R&D system hinder the development. The last from the German questions asks for the *completion of an efficient medical-care system achieved by systematising medical facilities* (J/G 15-100). While no technical problems are expected from this question and costs are estimated average (29%) the solution of this problem mainly poses institutional (42%) as well as cultural (46%) problems. The reorganisation of the medical system is one of the most substantial questions within the German social policy. The effectiveness of the existent system suffers from the way it is financed as well as from the distribution system, which both have an effect on the institutional and cultural constraints.

4.6.16 Culture and Lifestyles

Three topics in Japan (J/G 16-25; J/G 16-69; J/G 16-74) and two in Germany (J/G 16-1; J/G 16-25) were selected as efficient from the area of Culture and Lifestyles.

The first of the Japanese questions is also considered efficient in the German sample and concerns the *elucidation of mechanisms to stimulate cerebral and neural activities by handicraft* (J/G 16-25). While for the German question, both, technical constraints (13%) are below average and nobody mentions cost-problems, the first are considered as rather high in Japan (67%). In both countries, insufficiencies in the R&D system are an additional hindrance to the progress in this area (J: 37%, G: 33%), which in Japan is combined with the demand for more funding (22%) and improvements in the human resources (41%).

The second of the Japanese questions (J/G 16-69) deals with the *systematic organisation of learning programmes incorporating traditional crafts, arts and culture to enrich lifelong education*. The importance of this question was rated average (53 index points). With low constraints on the technical and cost level, most of the constraints are cultural aspects (51%), funding (44%) and deficits in human resources (25%). One reason might be the missing acceptance of such a system for traditional crafts and arts, which in Japan, are still regarded to be better learned by imitating the way a teacher does it.

Question J/G 16-74 considers the *development of an evaluation system, which focuses on thorough and broad personal abilities and will be able to replace the usual school entrance examinations.* As school entrance examinations play a considerable role in Japan this question got a comparatively high ranking of importance in Japan (72 index points). While only a few technical problems exist (18%) and costs are also low (3%) the main hindrance will be posed to this issue by institutional constraints (61%) as well as cultural ones (48%). Especially, the comparability of results from the described testing device will be doubted and therefore reduce social acceptance.

The last question to be discussed is from the German sample and asks for the *widespread use of personal nutritional indices, taking age, regional, and other individual differences into account, that are developed based upon the scientific elucidation of the interrelation between nutrition, metabolism, exercise and physical strengths* (J/G 16-1). This question is characterised by an importance index slightly above average (index 53), the non-existence of technical problems and few cost problems (14%). This combination of indices obscures high constraints especially on the cultural level (79%). As comments to this topic indicate, the answering experts did not expect technical problems but it is doubtful that the indices will be in Widespread Use because men are not as rational as machines and would not accept them. German experts also see the danger of being forced to behave according to indices and not related to their personal feelings and freedom.

4.6.17 Conclusions from the Most Efficient Innovation Projects

To summarise the results of the DEA analysis, many topics were identified which indicated a favourable relation between estimated importance of the topic and assumed cost and technical constraints on their realization. For some topics, these hindrances were easy to explain qualitatively, for others, further investigation would be necessary. Naturally, as the experts participating in the Delphi surveys were asked to choose *two* of the given constraint categories which they considered most important, the optimization by the DEA method of low cost and technical problems as gauged against importance selected topics with *other* constraints than these.

For technology policy, it may be interesting to learn which of the innovation projects as described by the Delphi topics and sorted out by efficiency analysis may be realized with relatively small budgets and modest technical problems. It was found that these developments mainly have to overcome adverse frame conditions which arise from the infrastructural (R&D system, legislation, funding, human capital) or cultural settings.

The most efficient topics in terms of money and technical problems for Japan and for Germany are largely *different* ones. As Japan admittedly has a less developed public R&D infrastructure in basic research than Germany, and Germany a better organised public movement opposing some new technologies than Japan, it is no wonder that the selected innovation projects being considered as efficient in Japan are connected to infrastructural problems in R&D. In Germany, vice versa, these are often related to areas with a lower public acceptance.

5 Conclusions

Growing competition on the world market and increasing technological change are forcing economies and organisations to concentrate their research and development (R&D) activities on selected areas. In order to identify those technologies which will have the greatest impact on economic competitiveness and social welfare, several new studies on critical technologies have been published in the United States, Japan and Europe. All these studies are written with the more or less expressive objective to sort out those technologies which are considered most important for the respective countries. They differ considerably in terms of size, disaggregation, methodology and relevance.

Among them is the Japanese Delphi which includes a comprehensive survey over two rounds with more than 1,000 technological topics included. The Delphi is considered to be highly oriented towards conformity though the huge statistical data base created does not automatically yield evaluations and recommendations. Based on the Delphi data pool, holistic assessments seem to be possible and they are provided within this report. The Japanese Delphi survey puts an established and validated methodology into practice and stresses the power of new technologies to remedy important societal and ecological problems.

Based on an overview of technology forecast activities in Japan, the Federal German Ministry for Research and Technology decided to engage in a Delphi survey parallel to the Japanese one in order to find out in how far it is suitable for the requirements of Germany. For a long time, the German government was not very active in technology foresight activities on a federal level. Recently, the unification of Germany and the corresponding tasks to restructure a former socialist economy as well as the budget constraints associated with the unification underlined the need for foresight in science and technology. A further argument to engage in technology foresight activities originates from the renewed emphasis in the United States and Japan.

The Delphi method is especially useful for long-range forecasting (20-30 years) as expert opinions are the only source of information available. The Delphi method was developed during the 1950's by a US corporation to make better use of the potential in group interaction. Questionnaires are sent to a group of experts over several rounds. The questionnaire of the second round does not only repeat the same questions but provides information about the degree of group consensus to the group members. The questionnaire is the medium for group interaction. General experience is that there is convergence of the panel estimates during the sequence of rounds. The panel members will usually have widely varying estimates on each questions in the first round and do not always shift their opinion under the influence of the assessments given by the other panellists. Delphi panellists have just as much opportunity to stick with their original views as do members of a face-to-face group. The advantage of a Delphi is that panel members can shift position without loosing face if they see convincing reasons for doing so.

There are two main problems with Delphi forecasting. The forecast questions asked in the first round must be generated elsewhere; they do not originate from the panellists. In this case, several Japanese committees and sub-committees generated the questionnaire based on previous surveys. Secondly, although technology is understood to be international in nature, experts selected from one country (even if their number is large) may collectively introduce a bias coming from implicit natural or cultural habits or collective information deficits.

As by far the best experience in large Delphi forecasting is available in Japan, where especially the Science and Technology Agency (STA) since 1971 uses this method every five years for its technology forecasting. It was decided to perform a German Delphi investigation principally along the Japanese guidelines (aims, inquiries, character and method).

In order to make the two investigations independent of each other ("double blind") it was arranged that despite a certain time lag, the German experts did not know any results from the Japanese sample. In both countries, about 3,000 experts have been addressed; the response rate in the first round is above 80 per cent in Japan, in Germany it is about 30 per cent. This seems to be low, but taking into account that Germany is doing such a survey for the first time, one is quite content with this response rate. In the second round, compared to the first, more than 80 per cent of the respondents participated in both countries.

There are two more reasons for a relatively low response rate in Germany only in the first round (in absolute terms, detailed and time-consuming questionnaire surveys like this one with a response above some 15 or 20 per cent are considered successful, as a rule of thumb). First, up to very recently the German government was not very active in technology foresight activities. With the notion of "unpredictability" of events in science and technology, this activity has neither been appreciated by other public science bodies. Therefore, the confidence of the respondents in meaningful results is assumed to be low. (One typical German respondent argued *"I hope that - in the best case - the policy impact of the Delphi will be zero. You cannot predict science. Government planners should know this. Strong priority setting enforces meaningless projects..."*.) The second reason is that - due to the pilot character of the survey in Germany - it was difficult to predetermine the most pertinent sub-area of expertise of each respondent. In Japan, the list of people to contact was well developed since the first such survey in 1971.

More than one third of the consulted experts in Germany as well as in Japan are employed at universities or other higher education facilities, about 40 per cent is from industry and about one quarter is from government laboratories, independent or non-profit institutions. The age peak of the respondents is between 50 and 60 years, the second most important age cohort is between 40 and 50 years in both countries. The time-consuming task to fine-tune the German sample by age cohort and employment and to match this to the Japanese model, finally paid off. No major differences in the way to answer the questions are expected from these factors.

The questionnaire is identical except some few topics which are specific to Japan and do not make sense in Europe (e. g. hybrid rice, cosmetics especially for Japanese skin). Altogether, 1,146 topics in 16 broader fields are included in both surveys and may be compared. The translation of the topics from the Japanese into German language was extremely tedious and difficult. Specialist translators experienced difficulties in grasping the general idea of the topics as the questions are not embedded in an overall context. They are used to translate coherent texts but not isolated single questions. Even the best technical specialist translators could not provide a version acceptable to technology experts in the field. Thus, the raw translations had to be revised by German scientists in each case, not being capable of understanding the Japanese language. Their version was checked again by the translators to prevent major discrepancy from the original version. There was no problem in "translating" geographical details from Japan. To give an example, the question on water quality in the Tôkyô Bay was substituted by asking for water quality in the Rhine river.

The objective of the Delphi investigation is to find out about the degree of importance assigned to the topics by the experts, the time of realization between 1995 and 2020, major constraints on realization or reasons for non-realization, the precision of time determination, the levels of present R&D performance and the necessity to co-operate internationally in pursuing technology progress. Also the degree of expertise of the panellists is self-estimated. The results of the Japanese investigations were published (in Japanese) in November 1992 and (in English) in summer 1993. The German investigation was also published in summer 1993.

Before some of the most interesting results are summarized below, it is important to note that not only does the analytical part of the Delphi survey provide important information for future technology policy but also that there is an impact on the panellists in the two countries themselves. Answering the questions and checking their opinion with the anonymous assessments of the other experts, a learning effect may occur among the participants in the survey. They were all provided with the estimates of the other panellists already in the course of the studies and could make free use of the information in their laboratories.

As for the analytical part of the study as a principal outcome, many results of the German survey are more or less the same as in Japan. In the first round, the German panellists seemed to rate the time of realization generally a few years earlier than the Japanese and tended to downplay technical obstacles. But in the second round by reflecting the distributions, the answers in both surveys approached each other (although the two national communities did not know each other's preliminary results). The second round underlined that the results were similar. In the final analysis of the *sum of all technology fields*, there was hardly any difference in the Japanese and German estimates. From this, there is evidence that the Delphi procedure does not depend on national influences and peculiarities very much. Progress in technology seems to be of really international nature in many fields with practically no information deficits in one of the major industrial countries. This leads to conclusions on the openness of world-wide scientific and

technological information (including Japan despite of the language barrier).
However, by looking closer at the details, at individual areas and single topics, *for several topics* strong discrepancies in both surveys are found and in many details the dominance of national communities and systems of innovation becomes obvious. The main conclusion for these cases would be that Delphi inquiries on technology should always be undertaken with an international panel including people from more than one country or continent. But for many topics no such extreme and simple results were found, but congruent and diverging results at a time.

To give some examples, there is a substantial difference between the Japanese and German estimations in the three areas of Space, Materials and Processing, and Culture and Lifestyles. One feature of the Culture and Lifestyles area is that topics contain many cultural constraints, which is due to the characteristics of the topics, and as for Space, Germany is proceeding with space research and development as a member of the European Space Agency, whereas most of Japan's space research and development is carried out independently, so that the gap between the two countries is quite prominent, here.

In the three areas of advanced technology (Materials and Processing, Information and Electronics and Life Sciences), German experts regard Materials and Processing as more important than their Japanese colleagues and are more optimistic about realization than the Japanese experts, while the Japanese experts believe that realization will be earlier in the Information and Electronics area. This seems to reflect the industrial specialisation of the two economies. The development of new material and process engineering is associated with the chemical industry which is one of the strong industries within Germany. On the other hand, Japan is among the world leaders in electronics and her electronic industry is considered as much stronger than the chemical sector.

The life sciences may also be associated with chemical industry along with food, agricultural or medical sectors. There is no notable gap in the area of Life Sciences. Japanese and German experts have different opinions about international co-operation in the three areas: in the Life Sciences area, the Japanese experts, and in the Materials and Processing area, the German experts believe there is a higher necessity for international co-operation.

On the other hand, in the three infrastructure areas (Urbanization and Construction, Communications and Transportation), both groups of experts share similar views about the degree of importance, however, the German experts forecasted an earlier realization time in Communications, while the Japanese experts predicted an earlier realization time in Transportation. In all three areas, German experts assume that there is a stronger need for international co-operation than the Japanese experts do.

Overall, German experts estimate international co-operation to be more important than Japanese experts do; however, the trend for Japan and Germany generally conforms in the ranking of these areas, and there are no major differences. On the whole, it is thought that the differences are a reflection of the geographical environment of the two countries. This is underlined in the analysis of technological stages by the fact that the perceived necessity of international co-operation for the topics in the Widespread Use stage is of considerably more relevance in Germany than in Japan. In a further reflection of this, although there is little difference between the two countries in the three advanced technology areas, German experts place more importance on international co-operation in the three infrastructure areas than Japanese experts do.

In an overall comparison of all variables in the two groups of technological areas mentioned above, in both Japan and Germany, more differences can be seen in technologies that are connected with the infrastructure. These technologies are more closely linked to society and the economy than the advanced technologies, whereas no major differences can be detected in the advanced technology areas, revealing that the relevance of science and technology for the society differs.

Regarding the relationship between importance and international co-operation, there is agreement between Japanese and German experts in the point that the need for international co-operation rises with the importance of the topic. The more important the technology is, the stronger is the need to promote that technology with a vision that reaches beyond national boundaries. This trend is a clear indication for the direction in which today's technology is progressing: the important technology today is *international technology*.

This shows that while there are differences between Japan and Germany in importance in relation to international co-operation and the R&D level, there is general conformity in both countries' assessments of the time of realization. The reason for this general agreement on the time scale is thought to be that science and technology today has become so globalised that in most cases, information about overseas achievements and R&D progress can be obtained relatively quickly, even when the own country is not actively involved in the R&D of that specific field. In contrast, the degree of importance of a technology is a reflection of the national state of science and technology, and the national characteristics itself, which is moulded by such factors as the socio-economic conditions or the history of the country.

On the other hand, as for the relationship between importance and the R&D level, German experts consider their own level of R&D to be high in topics with a high degree of importance, whereas in Japan, no clear relationship between the two criteria can be identified. One explanation for this is that in Germany, a high priority is given to R&D in important areas of science and technology, which - from the historical adjustment processes - resulted in a high R&D level, whereas Japan tackles a wide range of science and technology areas as a historical result of catching up.

As for the relationship between constraints and other parameters in the realization of the topic, major differences between Japan and Germany can be seen in the relationship between funding and human resources and the degree of importance. In Japan, as the importance increases, the percentage of experts that indicated constraints in funding and human resources rose sharply, while in Germany, there is no such trend. In the funding constraints, there is a need to take into account that the translation of what funding or capital shortage exactly means in German and Japanese language is difficult. In Germany, often cost problems were mentioned instead. These assessments are derived from personal judgements of Delphi panellists. No hard facts exist on the future and all limitations from the Delphi methodology should be kept in mind.

However, the difference between the two countries suggests that in Japan's case, there are still many aspects of major investments in long-term R&D, including funding and human resources that require improvement. This is underscored by the high percentage of Japanese experts that indicated these constraints in topics at the

Elucidation stage, i. e. basic research. Regarding constraints in the R&D system, in both countries, the constraint index tended to rise as the importance of the topic increased, implying that the present R&D systems are not developed or upgraded enough to keep pace with the rapid progresses in science and technology. This makes science and technology foresight for priority setting even more important.

To sort out the most efficient innovation projects from the Delphi questionnaire is not an easy task. Most of all, an operational definition of *efficiency* is required. If we put into relation low constraints with high importance for the individual topics we have a sort of an input-output concept and may calculate efficiency therefrom. Efficient topics would be those for which high importance levels coincide with few and low constraint levels. Efficient innovation themes are not necessarily those with top importance ratings but rather a favourable relation of high levels of importance associated with low levels of inputs.

The most efficient topics in terms of money and technical problems for Japan and for Germany are largely *different* ones. As Japan admittedly has a less developed public R&D infrastructure in basic research than Germany, and Germany a better organised public movement opposing some new technologies than Japan, it is no wonder that the selected innovation projects being considered as efficient in Japan are connected to infrastructural problems in R&D. In Germany, vice versa, these are often related to areas with a lower public acceptance.

To conclude, the international scope of technology foresight seems to be important as sufficient specialist experts may not be available in one country only. In sociology, most scientists assume that there is a positive relationship between involvement in a research area and assessments of it and that this relationship derives from the tendency of scientists to select problems in areas where there is high pay-off for successful solutions and career. The tendency to overrate fields in which a person works may be termed "bias". In the respective literature, not only a tendency toward positive bias for fields in which researchers have been active is documented, but also this bias seems to be stronger in less innovative sub-fields (defensive point of view). As market signals fail to be useful for business strategy in the long run and expert assessment is not always objective, Delphi surveys may play a part with a more objective information base in innovation management.

The Delphi data bases from Japan and from Germany, which are now available, seem to offer rich opportunities for further analysis both in terms of priority setting for technology policy and innovation strategy as well as for technology analysis.
The authors of this report will very much appreciate if further comments, remarks or critiques would be brought forward by the readers. If there are errors in the assessments or, due to the course of time, some information are outdated already, the NISTEP or the ISI Delphi teams would be grateful to be informed.

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