55. G. Wald, P. K. Brown, P. H. Smith, *J. Gen. Physiol.* **38**, 623 (1955).
56. See, for example, W. A. H. Rushton, *J. Opt. Soc. Am.* **53**, 104 (1963).
57. Well summarized by J. E. Dowling, *Science* **155**, 273 (1967).
58. M. Alpern, W. A. H. Rushton, S. Torii, *J. Physiol. (Lond.)* **206**, 193 (1970); *ibid.*, p. 209; *ibid.* **207**, 449 (1970); *ibid.*, p. 463.
59. W. A. H. Rushton, *Proc. Roy. Soc. Lond. Ser. B* **162**, 20 (1965).
60. M. G. F. Fuortes and A. L. Hodgkin, *J. Physiol. (Lond.)* **172**, 239 (1964).
61. This scheme involving feedback or "automatic gain control" [R. M. Boynton, *J. Opt. Soc. Am.* **53**, 165 (1963)] should be distinguished carefully from Kaissling's (*67*) notion for long very thin dendrites in which it is the distributed conductance changes due to the conductance-increasing stimulus that shunt the currents produced by additional stimuli, so that range compression occurs.
62. G. W. Hughes and L. Maffei, *J. Neurophysiol.* **29**, 333 (1966); see also L. Maffei, L. Cervetto, A. Fiorentini, *ibid.* **33**, 276 (1970).
63. R. M. Boynton and D. N. Whitten, *Science* **170**, 1423 (1970).
64. For example, if $I(x) = I_0 e^{-\beta x}$ and the steady-state fraction of pigment bleached at each $I(x)$ is $I(x)/[I(x) + Q]$ with Q constant, then the integrated fraction bleached over the receptor (or receptors) is
$$\left[\ln\left(1 + \frac{I_0}{Q}\right) - \ln\left(1 + \frac{I_0 e^{-\beta b}}{Q}\right)\right]/\beta b$$
so that the fraction bleached is about proportional to the logarithm of $(1 + I_0/Q)$ over a range determined by the size of β. Note that if the threshold ΔI for a visual response were proportional to I_0, as in the Weber-Fechner relationship, the S-shaped curves for bleaching plotted against threshold upon which Dowling and Wald remark for the rat retina [see, for example, figure 4 in G. Wald, P. K. Brown, I. R. Gibbons, *J. Opt. Soc. Am.* **53**, 20 (1963)] would be approximated. Such a comparison raises at least as many questions as it answers, because the same relationship is found when vitamin-A deficiency is substituted for the bleaching and because Dowling's curve for bleaching plotted against background illumination for the rat eye (*57*) is steeper, rather than more gradual, than the function $I/(I + Q)$.
65. See, for example, W. R. Loewenstein, *Cold Spring Harbor Symp. Quant. Biol.* **30**, 29 (1965).
66. E. Florey and E. Florey, *J. Gen. Physiol.* **39**, 69 (1955).
67. K.-E. Kaissling, in *Handbook of Sensory Physiology*, L. M. Beidler, Ed. (Springer, Berlin, 1971), vol. **4**, p. 351.
68. R. A. Steinbrecht and G. Kasang, *Wenner-Gren Center Symp. Ser. Olfaction Taste* **4**, 193 (1972).
69. R. A. Steinbrecht, personal communication.
70. K.-E. Kaissling and J. Thorson, in preparation.
71. F. Barth, *Z. Vergl. Physiol.* **55**, 407 (1967).
72. S. Landgren, *Acta Physiol. Scand.* **26**, 1 (1952); W. D. McCall and W. J. Williams, *Fed. Proc.* **30**, 709 (1971); K. Chapman and J. H. Pankhurst, in preparation.
73. K. M. Chapman, *Bol. Inst. Estud. Med. Biol. Mex.* **21**, 141 (1963).
74. D. Finkelstein and O.-J. Grüsser, *Science* **150**, 1050 (1965).
75. H. Mittelstaedt, *Verh. Dtsch. Zool. Ges. Wilhelmshaven Zool. Anz.* **16** (Suppl.), 150 (1952). The data of B in Fig. 3 (H. Mittelstaedt, unpublished data) average the responses of two animals.
76. B. Hassenstein, *Z. Natursforsch.* **14b**, 659 (1959).
77. W. E. Reichardt, *Cold Spring Harbor Symp. Quant. Biol.* **30**, 505 (1965).
78. Our interest in nonuniform photoexcitation in various materials was stimulated during a valued period of study (by J.T.) under Dr. Richard E. Halsted (deceased) at the General Electric Research Laboratory (Schenectady, N.Y.). We thank Drs. Kent Chapman, Fred Dodge, James T. Enright, Russell Fernald, Walter Heiligenberg, Karl-Ernst Kaissling, Kuno Kirschfeld, Henry P. Kramer, G. David Lange, R. W. Preisendorfer, Richard F. Reiss, and David C. S. White for critical discussions. We also thank Drs. Horst Mittelstaedt, John W. S. Pringle, and Theodore H. Bullock, in whose laboratories the analysis was developed, for their encouragement and hospitality. We gratefully acknowledge partial support from USAF Office of Scientific Research grants 67-1337, 67-1337A and EOAR 69-64.

Norway: Small Country Plans Civil Science and Technology

Experience suggests how cooperative applied science programs can be linked to national goals and needs.

James Brian Quinn and Robert Major

A 2½-year project to develop coordinated, long-range plans for a major portion of Norway's civil science and technology programs has recently been completed. This exercise, undertaken by the Royal Norwegian Council for Scientific and Industrial Research (NTNF), illustrates many of the problems and opportunities of such planning in a small country (Norway's population in 1970 was 3.9 million).

Norway's situation regarding science and technology is similar to that of many other countries. Norway has limited scientific and technical manpower resources—some 9000 degree-holders primarily engaged in research and development (R & D)—yet it must compete in its major export markets with large, technologically advanced countries. Norway's industrial structure contains few large companies, but many small ones. Consequently, government and private industry must cooperatively support R&D in many fields. Even so, Norway must, of necessity, import most of its scientific and technological knowledge. Since its natural resources are already being extensively exploited—except for recently discovered hydrocarbons in the North Sea—Norway must depend on knowledge industries for future economic growth. Like many other countries, Norway faces the modern challenges of continued economic growth, maintenance of a good quality of life in its cities, and enlightened development of its extensive rural areas. Sophisticated application of science and technology will be necessary to attack these problems. Norway's approaches and experiences could be of interest to many.

Dr. Quinn is Nathaniel Leverone professor of management, Dartmouth College, Hanover, New Hampshire 03755, and a consultant on long-range planning. Mr. Major is director of the Royal Norwegian Council for Scientific and Industrial Research, Box 279, Blindern Oslo 3, Norway.

Structure of Norwegian Science and Technology

Total expenditures for R & D in Norway were about 1100 million kroner in 1971, or approximately 1.2 percent of the gross national product. Table 1 shows how expenditures for R & D in Norway are distributed among sources of funds and performing institutions.

To stimulate and coordinate R & D in nonmilitary fields, there are three research councils: the Norwegian Council for Science and the Humanities, the Norwegian Agricultural Research Council, and the NTNF. Their activities cover virtually all subject areas except defense. The councils advise the ministries concerned with their respective fields, supervise certain research institutes, finance research projects and research capital needs, provide scholarships, and advise on education, training, and recruitment of scientific and technical personnel (*1*).

The NTNF

The NTNF was founded by a Resolution of Parliament in 1946 (*2*). It was established as an independent institution related to the government through the Ministry of Industry. The NTNF is financed by direct government grants, by receipts from the national football pool, and by contracts from industry and others (Table 2). The council itself consists of 30 members, with about equal representation from government departments, industries, and institutions performing research. The council has a six-man executive committee and some 20 advisory committees for various specialized fields.

The NTNF supports R&D activities for manufacturing industries, building and construction industries, shipping, transportation, communications, and various government functions such as town and regional planning and depollution. There are currently some 16 institutes affiliated with the NTNF covering these fields. But NTNF funds also help support research projects in universities, other applied research institutes, and industry.

In 1972, the NTNF spent some 168 million kroner on R & D; this expenditure represents an average annual growth rate of 14.4 percent (including atomic energy research) in recent years. These funds are extended considerably by industry and internationally sponsored research at institutes (82 million kroner), joint industry-government support of individual programs, and private companies spending their own funds to complete the development of successful research programs started with NTNF support. Supported scientific cadres further extend the impact of research funding through informal consultation, lecturing, evaluating foreign technologies, and other forms of participation in public life.

Long-Term Planning

At an early stage of the NTNF's development, grants were issued largely in response to specific proposals by individual scientists, groups, or institutes. While satisfactory for smaller scale operations, this practice led to fragmented programs, a myriad of small projects, and an orientation toward short-term projects. In the mid-1960's, the NTNF initiated a planning procedure that was primarily qualitative in nature. In 1969, it was recognized that the NTNF's growing scale, complexity, and impact required more formal and quantitative planning. The NTNF saw a need to: (i) take a longer term view, anticipating major scientific opportunites and technological threats in time to take effective action; (ii) blend fragmented projects into higher impact programs; (iii) balance these programs into a strategy for each sector and the NTNF as a whole; and (iv) be able to demonstrate specifically how the NTNF program supported national goals. A long-term planning program was established to accomplish these aims.

From the outset it was recognized that the planning procedure had to be decentralized in order to involve both research performers and users actively in the planning process. This was considered essential for both realistic plans and their implementation.

The total of NTNF activities was divided into some 21 sectors, representing specific industries, problem areas, or horizontal support fields (*3*). Each sector had a planning committee, most of which had already existed as advisory committees to the NTNF. These committees contained industrialists, government leaders, and scientists knowledgeable about the particular field. Committee chairmen were widely respected executives who usually occupied full-time positions in business or government. Each committee had a staff head (secretary) who could devote the greater part of his time to the committee. Secretaries typically came from the NTNF administrative group, an institute, or an industry group that sponsored substantial work with the NTNF. The committees were coordinated by a planning secretariat within the NTNF administration.

Table 1. Expenditures on R & D in Norway in 1971, distributed by sources of funds and types of institutions.

Institutions	Sources of funds				
	Government (%)	Industry (%)	Foreign (%)	Other (%)	Total (%)
Universities and colleges	95	1	1	3	32
Research institutes					
Government institutes	95	1	1	3	14
Institutes of research councils	74	17	8	1	12
Other institutes	45	40	2	13	10
Industrial laboratories	11	86	2	1	32
Total	61	34	2	3	100

Planning activities were divided into five phases: phase 1, perspective analysis; phase 2, obtaining goal perceptions; phase 3, establishing programs and priorities; phase 4, allocating resources; and phase 5, final report and follow-up. Each of these is briefly described and analyzed below.

Phase 1: Perspective Analysis

Each committee attempted to define during phase 1 (November 1969 to June 1970) the most important technological changes its sector was likely to create or face during the 1970's. These included the most probable opportunities, threats, trends, or impacts posed by science and technology within that sector. Committees considered available economic and social forecasts as a backdrop for their perspectives. They then decided what specific technological forecasts were needed, agreed on the best authority for each forecast, and specified the assumptions and format needed to make the forecasts compatible. Actual analyses and forecasts were commissioned or assigned to knowledgeable individuals or groups.

Based on these studies, each committee drew up a formal perspective analysis report at the end of phase 1. Some of these are quite strong; among others, those on electronics, metallurgy, and transport. In general, however, phase 1 was the weakest portion of the exercise. Some reports dwelled too long on descriptions of the existing structure of the industry. Others only projected generally available economic data and raised well-known cost, trade, or political issues that faced the sector. In still others, there was too little concrete forecasting of specific technological parameters, possibilities, or threats.

Problems in phase 1 derived from

several sources. Perspective analysis is perhaps the least structured and inherently most difficult process in long-range planning. The planning committees had no prior experience with this kind of analysis. Foreign consultants offered some seminars and training sessions, but no expertise was then available within the NTNF to guide the committees. Because the NTNF administration became overburdened, training sessions were begun late and it was difficult to supply guidance as issues arose later in phase 1.

Working committees encountered other difficulties. Knowledgeable private sources were understandably reluctant to share information that had been developed at significant cost or that was of great competitive value to themselves. Companies would not, of course, disclose to the public or to competitors the most exciting of their perceived opportunities or the most serious of their competitive threats. And with staff support limited, the part-time nature of committee participation often militated against the depth of analysis needed. Whenever desirable and feasible, special studies were commissioned with institutes or consulting groups.

Nevertheless, at the end of the exercise virtually all committees evaluated phase 1 as an essential process. The following quotations (by K.-E. Knudsen, chairman, Continental Shelf Division, and H.-P. Klemnetsen, secretary, Automation and Data Processing Committee, respectively) suggest the most commonly perceived benefits:

> Phase 1 was important to free up our thinking; to make us think about possibilities, not existing programs. It is important to politicians and society to know that we have done this.

> An essential step. We never would have arrived at our framework without it. We needed to get back and think about our whole field in a structured way.

The real value of phase 1 was not as much in the perspective analysis reports as in the thought processes they stimulated within the committees. Phase 1 was essential in the transition from annual budgetary planning to a longer term basis.

These analyses had a positive impact on the way most committees attacked later programming and allocation phases. They also provided an important means for involving influential groups outside the NTNF in the planning process.

Phase 2: Obtaining Goal Perceptions

Although the NTNF's programs were to serve national goals, it was decided not to start the planning process by attempting to state national goals explicitly. General statements of goals existed in the political parties' programs, and more specific goals had been set forth in such important public actions as the government's 4-year economic plan. But no single, agreed-upon, broad statement of goals existed within the government or society.

For the NTNF to draft such a statement for the country would have been presumptuous. Consequently, the NTNF attempted in phase 2 (July 1970 to June 1972) to create mechanisms through which it could obtain "useful perceptions" of national goals. Phase 1 provided a key element in the NTNF's obtaining such perceptions: it offered NTNF leaders concrete issues and data for discussions about goals, and it avoided simply initiating open-ended conversations on the amorphous topic of "national goals."

Phase 1 perspective analyses were summarized into background papers for a series of meetings with top-level political, ministerial, labor, industrial, and opinion leaders. Reactions to the opportunities and threats posed by these analyses were sought. No clear and definitive statements of national goals were announced in these meetings—nor were such statements expected. But they did develop a sense of what national goals relevant to NTNF activities were desired and acceptable. Some shifts in priorities were perceived. For example, antipollution priorities appeared much stronger than before. Other goals that had been under some attack were reinforced; for example, desired economic growth levels and the maintenance of regional balances.

After these meetings, the NTNF planning secretariat wrote a summary of perceived national goals for distribution to planning committees. This document develops three primary goals, along with derived goals and potential NTNF contributions. The Appendix contains some translated quotations to suggest the degree to which national goals could be made explicit at that time.

Although they were, of necessity, general, these goals proved adequate to guide later planning stages. On the basis of these goals and perspective analyses, the NTNF's executive committee and council approved certain "planning frames" for total NTNF expenditures and for each committee's potential outlays during the next 4 years (1972 to 1975) (Table 3). These frames provided probable upper and lower expenditure limits, reflecting changing priorities among areas. For example, sharp increases were allowed for continental shelf, mechanical industries, electronics, automation and electronic data processing, and pollution control activities. Atomic energy and space activities were essentially constrained to remain at existing expenditure levels. Other sectors varied between. The executive committee and council thus provided the first guides to overall strategy.

Using other available data, individual committees then refined these broad goals and frames into planning goals for their sectors. In certain sectors, more specific goals already existed in legislation or stated government objectives. In other cases, the committees made decisions based on their knowledge of the total Norwegian situation. Phase 3 (programming) and phase 5 (final) reports contain sections on sector and national goals and explicitly show how recommended programs support phase 2 goals.

Both the full council and the state secretaries (*4*) reviewed the stated goals and the major program balances supporting them. Reviews of plans and programs and the processes of formulating political policy offer additional opportunities for goal perceptions to be systematically tested, evaluated, and acted upon both within the NTNF system and at ministerial and parliamentary levels. As plans are updated, goals and programs can be further clarified or modified.

National goals are a composite of the constantly changing aspirations of all people and interest groups in a society. No single statement can capture all such goals, nor can any set of actions truly satisfy them. Because of such dynamics, the process of obtaining goal perceptions is as important as determining what the specific goals were. The NTNF has attempted to arrive at and modify its goal perceptions by a continuous process involving as many important decision centers as it seemed feasible to contact.

When they were interviewed after later programming stages, committee chairmen and secretaries usually stated that, despite its difficulties and the

vague nature of the national goals eventually distilled from the process, phase 2 was both necessary and helpful. The consensus was (i) that it was essential that political, labor, and industrial leaders feel that a genuine attempt was made to consult with them about the program's overall relationship to national goals as perceived by these groups, (ii) that there was a very real obligation for committees to show how their programs supported national goals, and (iii) that the goals generated were adequate for the purpose.

A rather typical viewpoint was expressed by R. Marstrander, secretary, Building and Construction Committee: "Stated national goals were vague but adequate. We understand the general political situation and policy anyway. The important thing is that the conversations took place."

There were several important weaknesses in phase 2. Because of their extensive regular commitments, political, economic, and opinion leaders contacted had limited time in which to absorb the perspective analyses as background for discussions of goals. Their responses in discussions were necessarily diffuse, and any attempt to summarize inevitably involved subjective selection and judgments. Because of limited personal contact with goal-setting groups, planning committees had to rely largely on the written summary of goals prepared by the planning secretariat. Further personal interactions between planning committees and the executive committee would have been helpful. Contacts with some influential groups were not too rewarding because of these groups' inadequate preparation or their biases. Finally, since this was a first experiment, both the NTNF and other parties had to work out their roles and modes of interaction. A constructive approach was begun. Much remains to be done, but most policy-makers contacted expressed a desire for continued dialogue.

Phase 3: Establishing Programs and Priorities

The activities in phase 3 (October 1970 to May 1971) (*5*) were the most similar to activities committee members had performed in the past. Nevertheless, outside consultants worked with individual members of the NTNF administrative groups and planning secretaries until these men became expert enough to lead seminars on critical R & D goal setting, program planning, and evaluation methodologies. Although the specific content of plans could vary according to the conditions of each sector, committees were expected to:

1) State the overall goals and R & D strategy of their sectors for 4 years (1972 to 1975).

2) Identify major fields within the sector where new knowledge was needed and formulate programs for the acquisition of such knowledge.

3) Consider whether the knowledge could best be imported or developed through Norwegian R & D.

4) Consider to what extent recommended R & D should be financed by the NTNF or by other sources.

5) Work out concrete plans for major programs to be supported between 1972 and 1975.

6) Evaluate each such program's potential contributions, resource requirements, and probability of success and establish priority among programs.

7) Based on these priorities, recommend programs to be carried out within the given lower expenditure frame and those to be supported within the upper frame.

8) Consider and recommend non–R & D programs needed to support proposed technical programs and sector goals.

The groundwork laid by phase 1 (perspective analysis) and phase 2 (obtaining goal perceptions) proved highly relevant. Most phase 3 (programming) reports related programs directly to industry structures, trends, opportunities, threats, and national goals defined in phases 1 and 2. A large percentage of phase 3 reports are of high quality. The reports on electronics, metallurgy, transportation, automation, shipping, and atomic energy (among others) were quite strong. Unfortunately, because of confidential information, not all of these are available to the public.

Perhaps the most difficult and critical aspect of programming was patterning programs selectively into sector strategies and avoiding the tendency to "do

Table 2. Sources of funds for NTNF in 1972.

Source	Funds (1000 Norwegian kroner)
Government grants	142,000
Football pool funds	23,500
Miscellaneous income	2,500
Net income	168,000
Income from contract research and international collaboration (estimated)	82,000
Gross budget	250,000

Table 3. Planning frames for NTNF R & D: Support for sample sectors.

Sector	Increase 1967 to 1971 (%)	1971 to 1975 increase (%)		
		Planning frames for committees in phase 3		NTNF-suggested frames in phase 5
		Lower	Higher	
Manufacturing industries				
Engineering	319	50	105	88
Electronics	90	65	113	67
Chemical	58	32	76	59
Metallurgical	62	49	81	60
Other industries				
Electricity supply, electric power	100	25	56	53
Building and construction	91	38	74	49
Shipbuilding, shipping	170	39	85	59
Domestic transportation	131	40	67	57
Special sectors				
Space	81	37	84	38
Atomic energy	11	− 8	1	0
Continental shelf	233	200	300	233
Town and regional planning	138	84	111	88
Pollution	248	69	113	68
Multisectoral fields				
Automation and electronic data processing	16*	46	77	52
Information activities	217	84	163	60
Fellowship programs	50	33	67	57

* Appears lower than actual. Other sectors also include some electronic data processing and automation activities. Data were reclassified to recognize most proper jurisdiction for projects as they developed.

a little of everything." Nevertheless, phase 3 plans often demonstrated increased concentration on fewer program areas, distinct shifts in priority among programs, explicit recognition of Norway's unique competencies and weaknesses, and specific consideration of technology importation or foreign cooperation. In some fields, thoroughly formulated strategies emerged and were clearly specified in the exercise. Two examples, atomic energy and inland transportation, will suggest the nature of such strategies in a small country.

Atomic energy: Norway has no real capacity to build reactors or even major systems components. Yet it has an established research capability in fuels, fuel testing, and fuels management. As an independent, small country, not identified with a specific reactor-producing country or industrial complex, Norway's expertise can be developed for consulting with architects-engineers, utilities, or buying countries. With environmental problems becoming a matter of greater concern, it should be possible to extend Norway's existing competencies in evaluating reactor fuels, safety, and effectiveness into consulting opportunities in these and associated areas. By evaluating worldwide technical progress, it has been possible to abandon certain programs and focus on points where an analysis of markets and suppliers showed possible opportunities for Norwegian expertise. Also suggested were areas in which further international cooperation was necessary to expand data bases needed to exploit these opportunities.

Inland transportation: Norway is a long, rugged country with a low population density, and there is a consensus that population concentration in urban areas should be counteracted. National transportation costs are therefore high. Norway produces ships and some railway coaches, but all automobiles and aircraft are imported. Consequently, major transportation research activities must be focused on the transportation infrastructure, the building of roads, aerodromes, and harbors, and on a balanced development among the different modes of transportation. Priorities in R & D are given to the study of future transportation requirements, future options for meeting these needs, the effects of various incentives and policies on transportation development, the effects of the transportation system on national costs and social development, the technical knowledge that is needed to evaluate and implement desirable transportation options, and the controlling of displacement effects as new modes of transportation are introduced.

In general, phase 3 programming was carried out effectively, but it too suffered some serious shortcomings: (i) groups such as the institutes performing research were sometimes not sufficiently involved in program design; (ii) there was not sufficient opportunity in this first exercise for desired interaction among sector committees; and (iii) a few committees tended to extrapolate past activities rather than develop thoroughly assessed strategies. However, a standardized programming format and reviews by the NTNF secretariat helped identify such problems and restore the desired focus.

Phase 4: Allocating Resources

On the basis of programs submitted, the executive committee provided new planning frames for each sector. Institutes and other research-performing bodies then submitted proposals extending up to 4 years in length to meet program objectives spelled out in phase 3. The process (from April to September 1971) allowed performers to propose technological approaches, maintained the decentralization of research-performing groups, and yet enabled activities to be coordinated toward user and social goals.

Research groups sometimes wanted to continue past programs that were of lower estimated impact, highly fragmented, or not appropriate to stated goals. Some committees—for example, the Automation and Data Handling Committee—enforced rapid compliance with goals and refused programs outside the desired framework. Others allowed existing programs to adjust at a slower rate. By the time budgets were being drawn up in fall 1972, almost all programs were responsive to programming goals.

In phases 3 (programming) and 4 (allocating resources) it was essential to protect the basic research and competency-building activities of institutes. It was also important to ensure adequate institutional support to allow for overheads, project starts and stops, and random timing in receipt of contracts or grants from industry or other sources. Sector committees and overall NTNF plans specifically reserved funds for these purposes. There were, of course, conflicting views as to the adequacy of such institutional support, with the institutes naturally preferring a higher percentage of funds not committed to specific goal-directed programs. Despite these and other inflexibilities caused by past budgeting, accounting, data, and management systems, planning began to influence and simplify budgetary activities as early as fall 1971.

Phase 5: Final Report and Follow-Up

The planning exercise was summarized in phase 5 (November 1971 to June 1972) in a final report that appears in two parts: part 1 expresses the overall goals and strategies developed and the key data for sectors; part 2 summarizes each committee's perspective analyses, strategies, and major programs.

A significant attempt has been made to relate the NTNF's total activities to national goals and to support programs within an overall strategy. Planning frames show the emphasis that should be placed on each sector in the next several years. Individual sector programs and the overall NTNF program are analyzed to show how they support important national goals. An attempt was made to describe certain high-impact programs, new initiatives proposed, activities coordinated across sector lines, flexibilities for further new initiatives, and basic research. Unfortunately, as so often happens, much of the "profile" of these proposals was lost during various discussions and reviews before the final summary report was released. One often needs to look beyond this document to the phase 3 reports to obtain a more complete sense of program strategy.

Of particular interest, however, are the policy guidelines used to develop and allocate programs. Most important are (i) maintaining a continuous "process" for discussion, analysis, and consultation on national goals; (ii) coordinating major technical programs toward these goals and specific user needs; (iii) maintaining the independence and strength of research-performing groups; (iv) concentrating fragmented projects wherever possible into high-impact programs; (v) adapting selected programs to unique Norwegian strengths or problems; (vi) utilizing foreign technology whenever it is less costly; (vii) creating strong com-

petitive capacities in carefully selected fields; (viii) developing a flexible scientific, technological, and information base; and (ix) providing research opportunities to enhance education and development of scientific personnel. These are all important concepts for a small country's civil science and technology programs. Written instructions, personnel training, and executive reviews reinforced these policies throughout the exercise.

Phase 5 served certain vital functions. It forced the NTNF to look at its commitments in a total strategic context rather than as a series of fragmented committee actions. It provided an important basis for communicating with all outside public and policy-making groups. And it created a focus for discussions about readjusting goals for the next planning cycle.

Certain portions of the NTNF plan will be updated annually. National goals will be reviewed, new planning frames provided, and major programs adjusted. Programming and final reports will summarize plans for the next 4 or 5 years, explain changes from earlier plans, and provide bases for budgetary and program control. Every 4 years the full planning cycle (including perspective analyses) will be repeated, in order to coincide with the government's economic planning.

The real test of planning, of course, comes in its implementation. If R & D programs respond to stated goals, and if these programs are more successful than otherwise, the main purpose is served. To date there has been a greater concentration of activities on, and a shift in emphasis toward, selected goals. Evaluating the results of programs will take some years. In the meantime, what has been accomplished? And what can be learned from the experience to date?

Primary Accomplishments

There were six primary, long-term benefits of the process.

The first was an increased understanding of and confidence in the program selection process. As expenditures on science and technology grew, it became increasingly important for the public and policy-makers to know that efforts in science and technology were being systematically related to national priorities. Active participation by political leaders, user groups, and researchers helped build an understanding of goals and programs. Discussion of plans in Parliament and the press will help to further disseminate information about the programs. For continued support, the understanding and confidence of these parties are essential. Public disenchantment and budget cuts for science and technology have repeatedly occurred in countries where such confidence has not been built. Planning has already provided a firmer and more objective basis for budget discussions within the NTNF system and the government. Ministry officials and private user groups have responded favorably, and other research councils have begun to see potential in the approach and to develop planning systems adapted to their own needs.

The second benefit was establishing a continuing discussion of national goals for science and technology. This difficult, but essential, process will continue. The attempt to systematically conceptualize broad goals and to relate major technical programs directly to them was an important advance. Although this had been done intuitively before, the planning process imposed a stricter discipline. Future modifications in approach will doubtless allow greater sophistication in both goal formulation and the evaluation of programs relative to goals. But a reasonable start has been made. State secretaries, industrial organizations, trade unions, and the employers' association have all expressed a desire to carry these discussions further.

Development of strategies for science and technology was the third benefit. The planning process forced decision-makers to face key choices and to design some genuine strategies for science and technology. Important shifts in priority were achieved. Decision-makers could see the overall balance and implications of programs recommended. Policy issues could be separated from the details of individual project proposals, and policy-makers could concentrate on the broad missions and program guidelines these proposals should support. Researchers knew what goals they were to support, yet were free to select technical approaches. This allowed central coordination toward goals, while continuing a highly decentralized and individualized conception of projects and performance of research. The following two examples of major priority shifts will give the flavor of the kinds of changes in emphasis achieved.

The electronics committee had previously supported a strong microelectronics program, plus a variety of other projects based on technical proposals received. Now the committee is continuing its microelectronics support, in the belief that future growth in electronics will require a close link with this technology, but it is concentrating its other programs in some seven areas (with emphasis on computer-aided design and biomedical and marine electronics) in which the country has some initial competencies and progressive, technically capable users. Within these areas, research is supported only if real needs can be identified. Special studies have been made of specific user groups' needs. The health directorate, for example, has been asked to define its equipment needs and, as a user, to share in supporting specific technical programs.

Because of anticipated social changes, the automation committee is now supporting new programs on unmanned production processes. Forecasts suggest that in the near future few Norwegian workers will want to work night shifts—and social values support the goal of workers living more normal family lives. Research is therefore under way on continuous metallurgical and chemical process controls to ensure that these production processes can run themselves at night with substantially reduced labor forces and adequate warning and emergency shutdown systems. This program will utilize the same kinds of systems and approaches adopted earlier for automating ships. The Norwegian data industry and potential users are being brought together to solve this problem in a timely fashion.

The fourth benefit was to concentrate projects into high-impact programs. Without well-defined programs to support, project proposals and approvals in many fields tended to be fragmented in the past. Program planning offered research groups opportunities to assemble sufficiently large program teams to be internationally competitive and to plan on longer term support for efficient R&D on problems with distant payoffs. Programming also provided a framework for focusing otherwise diffuse proposals and encouraging applied research in areas with a high priority or high potential impact. Two examples will suggest how the program concentration was achieved.

Because of the increased complexity and personnel costs of ship operations, an integrated program on many aspects

of improved ship and fleet operations has been undertaken. A number of separate projects in a variety of shipping companies, institutes, and disciplines have been brought together under a single program leader and steering committee. Projects include: new management methods for operating fleets at sea and in port, communication systems to run the ship as a quasi-autonomous unit in a worldwide system, design of living and work areas aboard ships to attract and keep qualified personnel to operate the ships, automated propulsion units and navigation equipment to maximize effective service time, and operations research and equipment studies to optimize maintenance, repair, and duty cycles. The ships are being studied as sociotechnical systems, relating human and machine activities aboard, overall organization of work, and the training and motivation of operating personnel. The objective of the integrated program is improved competitiveness for Norwegian shipping.

When planning started, there were research projects on various elements of building and construction systems in individual universities, institutes, and companies. Planning increased awareness and understanding of the need to tie together these different elements of architecture, social analysis, functional analysis, construction materials, and engineering concepts on an integrated basis. The building and construction committee is now giving priority to projects involving integrated concepts of building. It has a program group coordinating such projects, and it has encouraged a large construction company to investigate the possibility of starting a new venture in systems building. This could provide an initial market for research and for suppliers' developments in this field.

Training and education of staff was the fifth benefit. Informal management techniques had worked well when the NTNF was small, but by 1969 there was a real need for a second line of management and for more sophisticated planning and control techniques, which would allow delegation of authority. The planning cycle offered opportunites for some management training and experience in forecasting, goal setting, programming, and so on. And it forced control systems to be adjusted to broader scale program management needs. Program planning and control systems now provide an essential vehicle for the council, executive committee, and administration to delegate authority without abrogating their statutory responsibilities.

Increased awareness of critical relations between technology and social goals was the sixth benefit. Specific programs were begun or reemphasized to better utilize social science research and to further coordinate the NTNF's technical activities with such research. Two examples follow.

As in all developed countries, the cost and complexity of government and municipal services are increasing. The ordinary citizen finds it increasingly difficult to contact various agencies in an effective way. It takes ever greater amounts of a citizen's time to obtain correct information from agencies and to comply with their regulations. A proper data system would allow a citizen to go to a terminal in his local post office and get an immediate response to his questions or provide information to agencies with minimum effort. The NTNF is therefore helping to bring the Norwegian data-processing business together with the agencies to help develop improved communications systems in a timely fashion. This effort is a further extension into the public sector of the long-established NTNF philosophy of helping Norwegian producers develop technology to fulfill user requirements.

In its perspective analyses, the building and construction committee saw a need for a sociotechnical emphasis on problems in its sector. Technology in the construction industry is producing adverse effects on workers, organization structures, and building occupants and users. Through the committee, programs have been sponsored on processes for reducing noise levels, decreasing dust and particulate matter, improving air circulation for tunneling, and other activities. Studies were made of certain urban environments to better define the social and building parameters that should be considered in future construction in similar environments. Comparisons have been made between tunneling and above-ground construction in order to reach an acceptable balance between social dislocations and costs in urban transport systems. Contractors and unions are studying the effects of certain employer-worker administrative arrangements on attitudes and productivity.

Some form of more formal planning was essential at this stage in the development of Norway's civil science and technology program. The approach chosen was matched to the institutions, capacities, and problems of the NTNF at the time (*6*). Some concrete progress has been made to date, as we have noted. More is expected in the future.

Caveats

The Norwegian experience has also produced some caveats that may be of potential use to others. The following are some of the most important:

1) Involve user groups and policy-makers directly in planning. A carefully planned series of meetings is essential to bring the proper policy-makers, coordinators, users, and researchers together with the information they need to participate in goal setting, strategy formulation, and program design. User participation is especially important in applied R&D programs—to channel efforts toward valid goals, to avoid overly theoretical orientation and isolation of researchers, and to achieve the actual application of the results of the R&D. The process through which decisions are reached is as important as the decisions themselves. The process must develop confidence in, momentum for, and commitment to goals and programs. Superbly conceived and presented plans are worthless without a commitment to action.

2) Explicit national goals are not necessary to start with. It is virtually impossible to obtain an explicit statement of national goals as the starting point for planning. Even if obtained, such a statement might do little more than provide a focal point for otherwise fragmented opposition. A rather broad statement of goals can, however, be quite sufficient if properly developed. Work groups can amplify goals in their particular sectors, and more explicit goals will emerge from the patterns policy-makers set as they accept or reject specific proposals in science and technology. The most difficult problems lie in deciding whom to contact in the initial stages and in providing a specific format and needed background information for their discussions. In a democratic society, planners must avoid the tendency to seek solely the commentary of the intellectual elite, political leaders, and leaders of established institutions. A broad initial base of commentary and continued opportunities for discussion are essential. A genuine attempt must be made to demonstrate that programs support perceived goals.

3) Concentrate on options, programming, and uniqueness. In early

planning attempts there is a tendency to merely extend former budgetary practices. A conscious break must be made in order to imaginatively analyze new horizons and options and to focus on goals and selective strategies. The NTNF found it beneficial to separate the imaginative processes of perspective analysis and goal setting from more traditional, budget-oriented processes. It is essential in programming phases to concentrate on goals sought and action sequences needed rather than budget expenditures. This requires training, reorientation, and discipline for all. But most difficult is the development of a selective strategy. A smaller country can only develop its own technology in a few relatively limited fields. It must concentrate its efforts on these and establish systematic means for importing or monitoring other technologies. Selectivity requires commitment at all levels of the planning process. The use of differential expenditure "frames" was an essential device for the NTNF in setting priorities. Working committees had to be reminded of selectivity at all stages. The key element, however, must be careful investigation of program plans by policy-makers and allocation of funds on the basis of how well these plans support goals. To withstand the inevitable pressures from every group wanting "its share" of funds, the ultimate decision-making body must be small, politically sensitive, and preferably somewhat removed from direct political pressures.

4) Tie budgets to plans and update plans continually. Unless resources are committed to support plans, the plans will never be put into effect or even taken seriously. Hence budgets for the first year of the planning cycle should be a direct outgrowth of plans. As they are developed, future years' budgets should be evaluated against plans to determine whether there should be any deviations. And the plans themselves should be constantly updated to reflect changing environments, opportunities, and capacities. In Norway, phases 2 through 5 will recur annually, while perspective analyses will only be developed every fourth year. There will be a constant dialogue on goals.

5) Provide interim mechanisms to maintain morale. An initial planning cycle takes at least 2 to 2½ years. Since most people involved in the process must be part-time volunteers, positive measures are needed to maintain morale. Selection of effective chairmen and compatible and constructive work committees deserves top priority. Timely instructions and training for committees are essential to decrease frustration. Most important, the total process should be broken into phases, each requiring a formal report. This imposes a time limit on committees, allows some control over the quality of work, and provides an interim sense of accomplishment. A careful plan for the entire planning process should be designed before starting.

6) Organize and train for planning. Effective planning cannot simply be superimposed on the existing organization and its ongoing responsibilities. At the top level, there must be a small group that can dedicate substantial time to the many policy-level contacts that are necessary. This group must be small, yet have enough power to make the choices required by selective strategy. A large, diffuse committee cannot be expected to develop such a strategy. Professional staff assistance is also essential. Unfortunately, such skills tend to be scarce in smaller countries. Outside consultants and experts may be useful resources, but they must train local expertise or effective planning will cease when they leave.

Summary

Smaller countries—and even more advanced large countries—need to carefully plan and allocate their limited resources in civil science and technology for maximum impact in terms of national goals. Norway's recently completed 2½-year attempt at more formal planning in the civil-industrial sector may suggest some useful approaches to this complex problem. It should also offer helpful insights to those interested in broad-scale, government-private planning in science and technology elsewhere.

Appendix

[Source: Translation of NTNF working documents "Phase 2, national goals," Spring 1972.]

"Discussions held . . . seem to clearly indicate three basic national goals relevant to the R & D activities promoted by NTNF . . . :

"1) Increased prosperity through continued high economic growth: . . . From discussions which have taken place during phase 2, it has emerged that Norway is still seeking to maintain a high rate of economic growth (4–5% increase in GNP per annum), insuring, however, at the same time that economic growth is not achieved at the expense of human well-being or good environmental conditions. It has been stated that, to a much greater extent than at present, problems of welfare and environmental character ought to be included in evaluation of means and measures applied to achieve economic growth.

"Derived goals:

► High economic growth through increased productivity, increased efficiency in the industrial structure, further processing of raw materials and components, specialization.

► Rational exploitation of resources.

► Full employment.

► Increased mobility of labour and capital from low-productivity to high-productivity industry.

"2) Increased human well-being and improvement of the environment: It has been emphasized that increasing resources achieved through economic growth ought to be allocated to a greater extent toward obtaining increased human well-being by insuring good labor accommodations and holiday conditions, and maintaining as far as possible a clean environment.

"Derived goals:

► Increased well-being at the working place with appropriate organization, good working conditions, delegation, and possibility for participation in the decision-making process.

► Good housing and holiday conditions through appropriate planning and efficient building activities.

► Reduced pollution of water, air, and soil. Suitable handling of garbage, waste, and so on.

"3) Insuring satisfactory settlement and industrial localization from a geographical point of view: It has been pointed out that it is important to counteract the rapid concentration of economic life in a few central regions, a development caused by shifts from primary to secondary or tertiary industries stemming from inadequate development of a regional economy.

"Derived goals:

► Developing industries which are suitable for operation in nonurbanized areas.

► Developing transportation and telecommunication facilities to these districts.

► Transitional financial support in conjunction with development of regional economies.

References and Notes

1. For further details, see *Reviews of National Science Policy: Norway* (Office of Economic Cooperation and Development, Paris, 1970).
2. Stortingsproposisjon Nr. 65 (1945–46), "Om opprettelse av Norges Teknisk-Naturvitenskapelige Forskningsråd" [Parliamentary Proposition No. 65 (1945–46), "Concerning the establishment of the Norwegian Council for Scientific and Industrial Research"].
3. Electronics, mechanical industries, metallurgy, chemicals, textiles, forest products, furniture, graphics, mining, electricity supply, shipping and shipbuilding, building and construction, domestic transportation, town and regional planning, atomic energy, space, continental shelf, pollution, automation and electronic data processing, scientific information, and technical and scientific personnel.
4. The highest appointed official below the rank of minister.
5. Phase 2 continued after the phase 3 programming cycle began. It is now recognized that interpretation of goals must be a continuing process.
6. See *Science Policy Studies, Norway* (Office of Economic Cooperation and Development, Paris, 1971) for recommendations on science policy issues.