A REPORT ON THE INPUTS INTO SCIENTIFIC RESEARCH IN SRI LANKA*

BY
SHANTHA LIYANAGE, ASOKA DE SILVA
and SUSANTHA GOONATILAKE

BACKGROUND

Underdevelopment of science and technology in Third World[1] countries has been attributed to a number of causes. Among these are scarcity of financial resources, deficiencies in the state planning organizations and the planning methodology, inadequately trained manpower and a dependency syndrome. The development of science and technology (S&T) in Third World countries being an induced development, planning and coordinating of science and technology activities become important.

The need for proper mechanisms to plan and coordinate science and technology activities has been advocated forcefully in the post-independence era by Sri Lankan scientists.[2] Although attempts have been made to induce S&T planning processes in the country, these have either failed or become ineffective due to a variety of reasons. Among them are lack of appreciation of S&T at the highest political level, a failure to realize the vital nature of S&T inputs in socio-economic development, lack of human and financial resources, inefficiency of existing S&T infrastructures, and under-utilization and misdirection of S&T resources. Further, there has been no reliable S&T data base to guide decision makers to launch S&T programs and periodically assess then progress.

In Sri Lanka, a systematic and sustained effort to collect S&T statistics has not yet been made and large gaps still exist. The aim of this study is to provide some of these basic data--to quantify the volume, structure and direction of S&T resources in Sri Lanka.

PREVIOUS STUDIES ON THE DISBURSEMENT OF S&T ACTIVITIES

In the past decade several governmental and non-governmental instititutions, such as the National Science Council of Sri Lanka, Sri Lanka Institute for Development

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Administration, Manpower Planning Division of the Ministry of Plan Implementation, the CISIR, and the Sri Lanka Association for the Advancement of Science (SLAAS) have been involved at different periods in S&T resources studies. These organizations, however, were not directly involved in S&T resources studies on a regular basis.

The SLAAS (formally CAAS) has on several occasions stressed the need to maintain reliable statistics, and in fact conducted the first survey on S&T manpower.[3] This survey made an effort to include all officers in important scientific and technical institutions. However, only 60 percent of the scientists in public sector institutions were covered by the survey.

The first comprehensive and systematic survey of scientific and technical manpower was carried out by the National Science Council of Sri Lanka for the period 1972/73. The survey strictly adhered to the concepts and methodology suggested by UNESCO. The first questionnaire addressed to the Secretaries of Ministries, yielded a response rate of 100 percent. The second questionnaire, addressed to the Heads of Departments and requesting a list of names of scientists and engineers employed by the departments had a response rate of 80 percent. The last questionnaire, addressed to each individual scientist, had a return rate of 35 percent. A major outcome of this survey was the preparation of a *Directory of S&T Personnel in Sri Lanka*. The results of this survey revealed that the total number of scientists and engineers during 1972/73 period was 3430.

The National Science Council (NSC) undertook its second national survey of S&T manpower for the period 1977/78. A special feature was the use of a structured questionnaire for which detailed replies were sought directly from individuals. Under any circumstances such an elaborate survey of the entire "scientific community" would be a long, drawn-out exercise. In the NSC study, even after 12 months of sustained activity involving intensive persuasion, personal interviews and radio and news media publicity, the final response rate did not exceed 60 percent. The survey revealed that the number of scientists and engineers then engaged in S&T activities was 4567.[4]

In a recent effort to assess S&T manpower in Sri Lanka, the Institute for Development Administration carried-out a survey to prepare a directory of high level S&T manpower in the country for the 1983/84 period. Preparation of the directory is now underway.

The first attempt to survey research and development (R&D) expenditure was undertaken by the CISIR in 1970 for the period 1955-1966.[5] This survey covered only public sector institutions. The information obtained was based on actual expenditure recorded under R&D expenditure in government estimates. This procedure was found to be inadequate as budgetary items listed as "research" were not necessarily meant for research as defined in the survey. The amount of R&D expenditure was estimated to be in the region of 0.3 percent of GNP during the early 1960s.

The National Science Council also carried out a study of R&D expenditure in 1975; whereby the expenditure was estimated to be Rs 45.1 million (0.21 % of GDP) for that year.[6] These studies paved the way for developing an S&T data base for Sri Lanka.

AIMS AND METHODOLOGY OF THE STUDY

The present study was initiated by the National Science Policy Coordinating Committee of the Ministry of Plan Implementation as a supplementary exercise in their efforts to formulate a unified science policy for Sri Lanka. The main objectives of the study were to review the current state of science and technology in the country and to examine the problems affecting the utilization of manpower and financial resources devoted to research and development. The study aims at providing a basic data base for science policy studies. It intends to give a very broad picture of the national science and technology efforts and identify some constraints in conducting R&D in the country. This study concentrates primarily on inputs to R&D activities. The definitions and methodology used conform broadly to UNESCO guidelines and concepts on the measurement of S&T activities.[7]

Manpower data for the year 1984 and R&D expenditure data for the year 1983 are included. R&D activities in engineering and technology, and natural, agricultural, medical and social sciences and humanities are covered. A total of 503 private and public sector institutions were surveyed. Medical services and secondary schools were not included.

COVERAGE AND RESPONSE RATE

A variety of scientific and technical (S&T) institutions were covered in this study. In addition, an attempt was made to include all non-S&T institutions in the state sector. Scientists and engineers in all public sector institutions were thus covered extensively. The chief investigators also interviewed a cross section of research scientists and engineers. It should be noted that no attempt was made to include medical officers in health services and secondary school teachers in this survey, because of time constraints. A list of scientists to be surveyed was compiled after consulting several sources such as directories and institutional lists as well as the previous NSC (1977) survey list.

The survey was conducted through a circular letter issued by the Ministry of Plan Implementation. It gave background information to the survey and operational instructions on the manner in which three questionnaires referred to as A, B and C sought to draw out three types of information. Form A sought information on scientists, engineers, architects and technicians. It was to be completed by the personnel manager of the institute surveyed. The second questionnaire (Form B) was directed to the finance manager of the institution, and called for information on the financial resources allocated for research and/or other scientific activities. The third questionnaire (Form C) was to be completed by the head of the institution. It sought information pertaining to policy directions, research orientation, problems and constraints to research and the head's personal viewpoints on future directions.

The dispatch of questionnaires was followed by personal visits to the institutions by field investigators to assist the officers nominated by each institution to compile the necessary information. In many of the major state departments and institutions this follow-up work was quite difficult. The chief investigators also interviewed a cross-section of research scientists and engineers.

It is encouraging to note that in the public sector as a whole, 70 percent of the institutions provided the necessary information within eight weeks of commencement of the study. This number effectively accounted for more than 90 percent of the S&T efforts in the public sector of the country. A reconnaissance study indicated that the institutions which failed to respond represented only a small segment of the national S&T effort (less than 250 scientists and engineers).

On the other hand, the response from the private sector was very poor, mainly because a great majority of these institutions do not engage in R&D. It is also significant to note that, while all the state sector commercial banks and the only privately owned Sri Lankan bank provided all the information without any hesitation, the foreign owned commercial banks, without exception, failed to respond. Table 1 gives the extent of coverage. Computer-based data analysis was carried out using the facilities of the Department of Census and Statistics.

Table 1: RESPONSE TO QUESTIONNAIRE BY GENERAL STATUS OF INSTITUTIONS

Status of Institution	Total Issued	Replies	Response (%)
Government	280	264	94
Private	211	93	44
Private Non-Profit	12	10	83
TOTAL	503	367	73

Questionnaire A called for a listing of scientists, engineers and technicians. It sought information on age, sex, academic and professional qualifications, subject speciality and whether or not engaged in research and development activities. Since the study was concerned largely with inputs to S&T activities, biographical and bibliometric information relevant to output studies were excluded. The information regarding subject speciality was, in some cases, based on broad subject areas in which the person had his first or higher degree. This information, we believe, was adequate and meets the requirements of this study.

Questionnaire B called for information on intramural and extramural R&D expenditure. A simple apportioning of funds was requested with respect to capital (equipment, instruments, etc.) and recurrent (wages, travel, etc.). In many of the larger organizations handling heterogeneous and complex activities (e.g. Highways Department, Mahaweli Authority), the survey officials assisted the respective contact persons of the institutions to compile the necessary information. The major problem for many institutions was the difficulty in differentiating research and experimental development from service activities.

Teachers in the Higher Education Sector, are also expected to devote time to research. This time component had to be quantified for purposes of estimating the expenditure on R&D. This was done by requesting the relevant higher education institutions to specify the percentage of time their S&T personnel devoted for the different activities such as teaching, research and others. This apportioning of time was also recommended to those other institutions that carried out research activities along with other functions.

Questionnaire C sought answers for 13 structured questions relating to managerial problems and constraints to scientific research. Many of the problems are very well known, yet each such problem is the result of different causes that affect each institution in diverse ways. Thus the purpose of this questionnaire was to help identify those heterogeneous and diverse issues which affect the performance of research.

SURVEY OF RESULTS

The total number of scientists and engineers engaged in S&T activities in Sri Lanka was estimated to be 7221. Out of this, 34 percent were natural scientists, 43 percent were engineers and technologists, five percent were medical scientists, and 18 percent were social scientists. Economically active natural scientists and engineers numbered 5557 in 1984 compared to 4567 in 1978. This corresponds to an average annual increase of 2.5 percent (141 persons per year).

The public sector continues to be the major source of S&T activity in the country, employing 92 percent of the economically active scientists and engineers and providing 93 percent of the national R&D expenditure. The number of scientists and engineers engaged in R&D activities amounts to 33 percent of all the economically active scientists and engineers. Only ten percent were classified as engineers and technologists. Only 15 percent are women. At 1970 constant prices (based on GDP), total direct R&D expenditure increased only marginally, from Rs.25 million (1975) to Rs. 33.4 million (1983).

As a percentage of GDP, R&D expenditure declined from 0.2 percent (1975) to 0.14 percent (1983). Per capita R&D expenditure in 1984 was around US$0.40, down seven cents from 1975. Fifty-eight percent of national R&D expenditure was incurred in agriculture. The number of full-time equivalent R&D scientists and engineers per million population was 79 (1984), the average for developing countiries being 125 in 1980. Basic research constitutes only eight percent of gross expenditure on R&D. The expenditure is heavily weighted toward applied research. In some state sector employment, total emoluments of scientists and engineers are nearly twice that obtained in equivalent positions within the sector.

The total number of economically active scientists and those engaged in research is given in Table 2. Twenty five percent of this total were scientists, 32 percent were engineers and architects, three percent were medical scientists, 13 percent were social scientists, and the remaining 27 percent were technicians. The total number of architects was 39. More than 60 percent of the scientific and technical manpower was under 30 years of age. Of them, 2951 (30%) were engaged in R&D activities.

Table 2: ECONOMICALLY ACTIVE SCIENTISTS & ENGINEERS IN SRI LANKA*

	Scientists	Engineers	Medical	Social	Technicians	Architects
Engaged in All S&T Activities						
Male	2025 (82%)	2894 (94%)	221 (66%)	965 (75%)	2229 (85%)	24 (62%)
Female	457 (18)	181 (6)	115 (34)	324 (25)	387 (15)	15 (38)
TOTAL	2482 (100%)	336 (100%)	336 (100%)	1289 (100%)	2616 (100%)	39 (100%)
Engaged in R&D						
Male	962 (73%)	223 (91%)	136 (67%)	487 (80%)	444 (76%)	2 (50%)
Female	340 (27)	21 (9)	66 (33)	124 (20)	144 (24)	2 (50)
TOTAL	1302 (100%)	244 (100%)	202 (100%)	611 (100%)	588 (100%)	4 (100%)

	All S&T Activities	R&D Activities
Male	8355 (85%)	2254 (76%)
Female	1479 (15)	697 (24)
TOTAL	9834 (100%)	2951 (100%)

*Excluding secondary school teachers and medical officers in the health services. The number of graduate science teachers and medical dates is estimated to be 2242 and 1667, respectively.

Economically active natural scientists and engineers in the country constitute a very small percentage (0.13%) of the total employed population in Sri Lanka.[8] Further, they represent only two percent of the professional, technical and related workers. Table 3 shows that the national scientific and technical manpower is heavily weighted in favour of state sector institutions.

Table 3: **TOTAL NUMBER OF ECONOMICALLY ACTIVE NATURAL SCIENTISTS AND ENGINEERS IN SRI LANKA DURING 1984**

	State Sector	Private Sector	STotal
Scientists - Male	1891	134	2025
Female	449	8	457
Total	2340 (94%)	142 (6%)	2482 (100%)
Engineers - Male	2588	306	2894
Female	176	5	181
Total	2764 (90%)	311 (10%)	3075 (100%)
TOTAL Scientists and Engineers	5104 (92%)	453 (8%)	5557 (100%)

A large percentage (59%) of natural scientists and engineers were employed by those institutions conducting general services. The institutions in the productive and higher education sectors accounted for the employment of 28 percent and 13 percent respectively (Table 4).

Table 4: **DISTRIBUTION OF NATURAL SCIENTISTS AND ENGINEERS ACCORDING TO SECTOR OF EMPLOYMENT**

	Scientists			Engineers		
	Male	Female	STotal	Male	Female	STotal
General Service	1034	271	1305 (53%)	1860	136	1996 (65%)
Production	614	37	651 (26)	892	29	921 (30)
Higher Education	377	149	526 (21)	142	16	158 (5)
TOTAL	2025	457	2482 (100%)	2894	181	3075 (100%)

Most of the scientists and engineers in the survey were employed on a full-time basis. Only six out of 2479 scientists and 21 of the 3070 engineers were employed on a part-time basis. There were 69 foreign consultants--17 scientists and 52 engineers. A significant number (208 scientists and 95 engineers) were abroad for long term specialized training. According to age distribution, 43 percent of the scientists--the largest segment--were in the 30-39 years age group (Table 5).

Table 5: DISTRIBUTION OF SCIENTISTS AND ENGINEERS ACCORDING TO AGE CATEGORIES

Age Group	Scientists	Engineers	STotal
Up to 29	569	760	1329 (24%)
30-39	1071	1202	2273 (41)
40-49	501	605	1106 (20)
50-59	227	288	515 (9)
60+	21	41	62 (1)
Unspecified	93	179	272 (5)
TOTAL	2482	3075	5557 (100%)

The distribution of all scientists according to their field of specialization shows a high concentration in agricultural sciences (46%), followed by natural sciences 37 percent, and engineering and technology 12 percent. Table 6 reflects these figures.

Table 6: DISTRIBUTION OF NATURAL SCIENTISTS AND ENGINEERS ACCORDING TO FIELD OF SCIENCE

	Scientists				Engineers			
	Male	Female	Total		Male	Female	Total	
Natural Sciences	679	236	915	(37%)	560	48	608	(20%)
Agri.Sciences	958	177	1135	(46)	113	2	115	(4)
Engi. & Techn.	289	22	311	(12)	2158	131	2289	(74)
Medical Sciences	9	5	149	(1)	1	--	1	(--)
Social Sciences	90	17	107	(4)	62	--	62	(2)
Total	2025	457	2482	(100%)	2894	181	3075	(100%)

The level of educational attainment of S&T personnel is a partial indicator of the quality of the workforce. The number of post-graduates is quite small (Table 7).

Table 7: **EDUCATIONAL ATTAINMENT OF SCIENTISTS AND ENGINEERS**

	Scientists	Engineers	STotal
Doctoral	302 (12%)	57 (2%)	359
Masters	337 (14)	180 (6)	517
Dip. (Post-graduate)	40 (2)	99 (3)	139
Bachelor	1369 (55)	1946 (63)	3315
Other	434 (17)	793 (26)	1227
TOTAL	2482 (100%)	3075 (100%)	5557

A large percentage of natural scientists (52%) are engaged in research activities. They represent about 44 percent of all researchers in the country. Among these natural scientists who engaged in research 41 percent were agriculturists. Only eight percent of the engineers were involved in R&D activities, leaving a large potential of talented engineers available for R&D work. Another important feature of the R&D workforce is the distribution of a large number of researchers in the universities (Table 8).

Table 8: **SCIENTISTS AND ENGINEERS AVAILABLE FOR R&D ACTIVITIES BY SECTOR OF PERFORMANCE**

	Scientists			Engineers			
	Male	Female	STotal	Male	Female	STotal	STotal
General	526	185	711 (87%)	98	9	107 (13)	818 (100%)
Production	80	10	90 (86%)	14	1	15 (14)	105 (100%)
Education	358	140	503 (80%)	112	11	123 (20)	626 (100%)
TOTAL	964	340	1304	224	21	245	1549

It is important to note that although the number involved in R&D work in higher education is relatively large, the actual number of full-time equivalents would be small due to the dual function of teaching and research--teaching being the predominant activity. It is beyond the scope of this study to make a detailed estimate of these separate activities by university staff. However, some estimates are given in the University Statistics published by the University Grants Commission.[9]

It should also be noted that only the major research institutions are employing full-time researchers. The total number of scientists and engineers in major research institutions, who are predominantly involved in R&D, amounts to 635. The remaining researchers are part-time employees.

The distribution of R&D scientists and engineers according to field of activities shows that a large percentage is concentrated in agricultural sciences. Tables 9 and 10 list some of the major groupings according to fields of specialization.

Table 9: **R&D SCIENTISTS AND ENGINEERS ACCORDING TO MAJOR FIELDS OF SPECIALIZATION**

	Scientists			Engineers			
	Male	Female	STotal	Male	Female	STotal	STotal
Natural Science	489	188	677 (86%)	102	11	113 (14)	790 (100%)
Agri. Science	400	133	533 (97)	15	2	17 (3)	550 (100)
Eng.&Tech.	46	8	54 (32)	107	8	115 (68)	169 (100)
Medical Science	10	4	14 (100)	--	--	--	14 (100)
Social Science	19	7	26 (100)	--	--	--	26 (100)
TOTAL	964	340	1304	224	21	245	1549

Table 10: **NUMBER OF R&D SCIENTISTS & ENGINEERS IN TOP 10 SPECIALITIES**

Scientists		Engineers	
Chemistry	272	Civil Engineers	1160
Analytical chemists	34	Mechanical Engineers	544
Bio chemists	19	Electrical Engineers	398
Botanists	115	Electronic Engineers	192
Micro biologists	24	Sanitary Engineers	150
Bio chemists	14	Chemical Engineers	102
Mathematicians	98	Production Engineers	20
Geologists	67	Mining Engineers	13
Zoologists	62	Telecommunications	11
Marine Biologists	14	Structural Engineers	10
Physicists	61	Industrial Engineers	9
Surveyors	40	Meteorologists	24

Table 10 (cont'd):

Agriculturalists			
Agronomists	246	Dairy Technologists	88
Entomologists	45	Food Scientists	32
Agri. Statisticians	32	Plant Breeders	31
Agri. Economists	28	Horticulture	25
Soil Scientists	19	Pathologists	17

In the case of scientists in particular, post-graduate qualifications are important indicators of the extent of specialized training. Speciality of engineers is often indicated by the professional qualifications. Table 11 shows the distribution of scientists and engineers according to academic qualifications. A large percentage of highly qualified manpower is concentrated in the higher education sector.

Table 11: NUMBER OF POST-GRADUATE R&D SCIENTISTS AND ENGINEERS BY SECTOR OF PERFORMANCE

	Diploma (Post-Grad.)			Masters Science			Doctorate		
	Eng.	Sci.	STotal	Eng.	Sci.	STotal	Eng.	Sci.	STotal
General Service	3	15	18 (85%)	9	175	184 (67%)	4	107	111 (34%)
Production	2	--	2 (10)	15	3	18 (7)	6	--	6 (2)
Education	1	--	1 (5)	20	53	73 (26)	31	175	206 (64)
TOTAL	6	15	21 (100%)	44	231	275 (100%)	41	282	323 (100%)

Table 12 illustrates the age distribution of S&T manpower for R&D activities in the country. The results show that a large percentage of scientists and engineers in R&D are distributed in the age group below 40 years.

Table 12: DISTRIBUTION OF R&D SCIENTISTS & ENGINEERS ACCORDING TO AGE CATEGORIES

	Under 29	30-39	40-49	50-59	60+	STotal
Scientists	395	557	237	103	12	1304 (84%)
Engineers	83	103	45	9	5	245 (16)
TOTAL	478	660	282	112	17	1549 (100%)

According to the Health Ministry Statistics, there were 1667 medical officers in the health services of the Ministry in 1984. The present study, however, did not include those medical officers due to resource and time constraints. A number of state and private sector institutions employed medical scientists for various S&T activities. Such medical scientists were included in this survey. Their numbers amounted to 336. Most of them were employed in the state sector (95%). Thirty-four percent of the total were women. Social scientists engaged in S&T activities were mostly employed by the state sector (98%). Twenty-five percent of the total were women. Fifteen percent of the 2616 technical personnel engaged in S&T activities were women.

Table 13: **DISTRIBUTION OF MEDICAL, SOCIAL SCIENTISTS AND TECHNICIANS BY GENERAL SECTOR OF EMPLOY-MENT AND SEX**

		Medical	Social	Technicians
Public	Male	205 (64%)	838 (73%)	2045 (84%)
	Female	114 (36)	316 (27)	383 (14)
	STotal	319 (100%)	1152 (100%)	2428 (100%)
Private	Male	16 (94%)	128 (95%)	184 (98%)
	Female	1 (6)	7 (5)	4 (2)
	STotal	17 (100%)	135 (100%)	188 (100%)
TOTAL		336	1289	2616

The distribution of these categories of personnel according to sector of employment is given in Table 14. A high percentage (57%) of the medical scientists were employed in higher education.

Table 14: **DISTRIBUTION OF MEDICAL AND SOCIAL SCIENTISTS AND TECHNICIANS ENGAGED IN S&T ACTIVITIES BY SECTOR**

	Medical	Social	Technicians
General Service	93 (28%)	625 (48%)	1702 (65%)
Productive	50 (15)	269 (21)	674 (26)
Education	193 (57)	395 (31)	237 (9)
TOTAL	336 (100%)	1289 (100%)	2616 (100%)

The percentages of medical and social scientists and technicians engaged in R&D activities were 14 percent, 44 percent and 42 percent respectively (Table 15).

Table 15: **Availability of Medical and Social Scientists and Technicians for R&D Work--1984**

	Medical	Social	Technicians
Public	198 (98%)	596 (97%)	584 (99%)
Private	4 (2)	15 (3)	4 (1)
TOTAL	202 (100%)	611 (100%)	588 (100%)

Research and development activities undertaken in private and public sector institutions varied from occasional to regular for the 130 institutions surveyed. Of this number, 80 institutions conducted R&D activity regularly, while 36 institutions had a separate R&D budget. The identification of R&D expenditure was very difficult in institutions where R&D activity was carried out only occasionally. R&D expenditure could be accurately identified in only 54 institutions. Therefore, unlike in the manpower statistics, R&D expenditure statistics were difficult to compile.

Even in major research institutes considerable amount of resources were not spent on research, but on "related scientific activities" such as routine testing, extension service, information services, seminars and consultancy work. The expenditure incurred on such activities was difficult to separate from R&D activities. In the higher education sector, the actual R&D expenditure was very difficult to identify from the university budgets.

There were also some difficulties in measuring R&D expenditure within institutes of research. Research and development activities are often understood and interpreted differently by different individuals. The accounting procedure for R&D expenditure also varied from institution to institution. Although the Institute of Chartered Accountants in Sri Lanka has recognized this problem and adopted standards for treating research and development since 1980[10], only a few institutions have strictly followed these procedures. The total R&D expenditure during 1983 was reported to be Rs. 162.65 million, of which 93 percent was accounted for by the state sector (Table 16).

Table 16: **GROSS NATIONAL R&D EXPENDITURE IN SRI LANKA DURING 1983 BY STATE AND PRIVATE SECTORS (RS. 000,000)**

	Recurrent	Capital	STotal
Public	110.441 (73%)	40.944 (27%)	151.385
Private	6.899 (61)	4.367 (39)	11.266
TOTAL	117.340 (100%)	45.312 (100%)	162.651

In the private sector, the ratio between recurrent and capital expenditure was slightly higher than in the public sector. According to the sector of performance (Table 17), R&D expenditure is largely concentrated (76%) in the general services sector. Both the productive sector and higher education sector in Sri Lanka had more or less similar expenditure levels. R&D inputs in the productive sector declined in comparison with earlier surveys. In the higher education sector, R&D expenditure constitutes directly identifiable expenditure in the university budget and a component of estimated academic services directed to R&D. In some rare occasions, university staff receive individual grants directly from foreign agencies. They have not been identified here.

Table 17: **R&D EXPENDITURE BY SECTOR OF PERFORMANCE* (RS. 000,000)**

	Recurrent		Capital		
	Salary	Others	Equipment	Others	STotal
General	60.7 (71%)	22.8 (73%)	12.1 (75%)	27.3 (93%)	122.9 (76%)
Production	9.9 (11)	5.0 (16)	3.4 (21)	2.0 (7)	20.3 (12)
Education	15.3 (18)	3.5 (11)	0.6 (4)	12.4 (-)	19.5 (12)
TOTAL	85.9 (100%)	31.4 (100%)	16.1 (100%)	29.2 (100%)	162.7 (100%)

*The proportion of academic services attributable to R&D in the Universities was calculated using the University Grants Commission statistics (UGC 1982).

R&D expenditure according to field of science is reflected in Table 18. Agricultural research received the highest percentage, whereas medical research had the lowest. The trend was very much similar to the findings of previous surveys.

Table 19: **R&D EXPENDITURE BY FIELD OF SCIENCE (RS. 000,000)**

	Recurrent		Capital		
	Salary	Others	Equipment	Others	STotal
Natural	13.5 (16%)	4.0 (13%)	4.9 (30%)	1.7 (6%)	24.0 (15%)
Agricultural	47.6 (55)	18.3 (58)	8.8 (55)	20.0 (68)	94.5 (58)
Engineering	6.7 (8)	4.0 (13)	1.8 (11)	7.7 (26)	20.0 (12)
Medical	5.5 (6)	2.8 (9)	0.5 (3)	--	8.5 (5)
Social	12.6 (15)	2.4 (7)	0.2 (1)	--	15.1 (10)
TOTAL	86.0 (100%)	31.4 (100%)	16.0 (100%)	29.0 (100%)	162.7 (100%)

There are a number of institutions which reported "Related" scientific activities as shown in Table 19.

Table 19: **EXPENDITURE ON RELATED S&T ACTIVITIES REPORTED BY THE INSTITUTION CONDUCTING R&D ACTIVITIES (RS. 000,000)**

	Recurrent		Capital		
	Salary	Others	Equip.	Others	STotal
Natural	20.3 (66%)	12.8	2.7 (30%)	0.4 (3%)	36.2 (50%)
Agricultural*	1.8 (6)	0.8	0.3 (3)	--	2.9 (4)
Engineering	1.4 (4)	0.4	5.5 (64)	11.9 (97)	19.3 (27)
Medical	3.9 (13)	0.2	0.1 (1)	--	4.2 (6)
Social	3.6 (11)	5.5	0.1 (2)	--	9.2 (13)
TOTAL	31.0 (100%)	19.7	8.8 (100%)	12.4 (100%)	71.8 (100%)

*This expenditure does not represent the extension services of the Department of Agriculture.

One of the striking features of related S&T activities is the low expenditure allocated to them by private industries. Private sector institutions were largely involved in R&D activities in relation to specific processes and products development. The extent of contracted research from some institutions to research agencies, research institutes and universities is presented in Table 20.

Table 20: **EXTRAMURAL R&D EXPENDITURE (RS. 000,000)**

	Recurrent		Capital		
	Salary	Others	Equipment	Others	STotal
Natural	0.6 (72%)	2.4 (35%)	1.8 (36%)	0.4 (99%)	5.2 (39%)
Agricultural	--	0.9 (14)	0.1 (3)	--	1.1 (8)
Engineering	--	--	2.7 (52)	--	2.8 (21)
Medical	0.2 (28)	2.9 (43)	0.5 (9)	--	3.6 (28)
Social	--	0.5 (7)	--	--	0.5 (4)
TOTAL	0.8 (100%)	6.8 (100%)	5.2 (100%)	0.4 (99%)	13.2 (100%)

The recipients of most of the contracted research have been state sector institutions and the funding bodies are also in the state sector. There are hardly any private research agencies to undertake contract research in natural sciences, although such associations do exist for social science research. Sources of funding R&D activities are given in Table 21. A large part is generated by government institutions. Foreign funds also constitute a significant 12 percent share of funding.

Table 21: **R&D EXPENDITURE FROM LOCAL OR FOREIGN FUNDS (RS. 000,000)**

	Natural	Agricultural	Engineering	Medical	Social
Local	21.3 (89%)	88.4 (93%)	13.1 (65%)	6.1 (70%)	14.6 (96%)
Foreign	2.7 (11)	6.2 (7)	7.0 (35)	2.7 (30)	0.6 (4)
TOTAL	24.0 (100%)	94.7 (100%)	20.1 (100%)	8.7 (100%)	15.1 (100%)

Table 22 gives a breakdown of R&D expenditure according to type of activities such as basic, applied, and experimental development. The commitment to basic research is generally low. A large part of basic research support came from public sector institutions. Most of the general service sector tends to undertake more of the experimental development type of research. Medical sciences reported very high percentages of basic research which was mainly supported by higher education.

Table 22: **R&D EXPENDITURE BY TYPE OF ACTIVITY AND FIELD OF SCIENCE (Rs. 000,000)**

	Basic	Applied	Experimental	TOTAL
Natural	1.3 (5%)	18.7 (78)	4.1 (17)	24.0 (100%)
Agricultural	5.7 (6%)	69.0 (73)	20.0 (21)	94.7 (100%)
Engineering	1.1 (5%)	12.7 (64)	6.3 (31)	20.1 (100%)
Medical	4.3 (50%)	4.1 (47)	0.2 (3)	8.7 (100%)
Social	0.5 (3%)	14.7 (97)	--	15.1 (100%)
STotal	12.8	119.2	30.6	162.6

Historical Statistics on S&T Activities in Sri Lanka

Growth of science and technology as measured by inputs may be taken as one indicator of the state of science and technology in Sri Lanka[12]. The development of indicators requires historical statistics which are comparable. Unfortunately, S&T statistics available in Sri Lanka do not permit such long term comparisons. The only surveys which can be compared with the present study in terms of coverage, scope and definitions were the 1977/78 surveys of S&T Manpower of the National Science Council and the 1977 study of R&D Expenditure by the same organization.[13]

Table 23 presents the growth of scientists and engineers (including medical prsonnel in S&T institutes and social scientists for 1984) during 1977/78 to 1984. The annual growth rate excluding social sciences for the period shows 3.6 percent increase in total S&T manpower and seven percent increase in full-time equivalent R&D manpower.

Table 23: **GROWTH OF ECONOMICALLY ACTIVE SCIENTISTS AND ENGINEERS BY FIELD OF SCIENCE 1977/78-1984**

	1977/78 No.	1984 No.	Average Annual Growth (%)
Natural	1074	1523	6.0
Agricultural	869	1250	6.3
Engineering	2420	2642	1.0
Medical	204	351	10.3
Social	N/A	1455	--
TOTAL	4567	7221	40.0*

*Excluding Social Sciences.

It is important to note that the full-time equivalent researchers in engineering and technology only amounts to three percent of the economically active engineers and technologists in the country. The agriculture sector was responsible for the highest percentage of researchers (42% of the agriculturists in the country). Table 24 presents the growth of research scientists and engineers by field of sciences from 1977/78 to 1984.

Table 24: **GROWTH OF ALL RESEARCH SCIENTISTS AND ENGINEERS BY FIELD OF SCIENCE FROM 1977/78-1984**

	1977/78 No. (FTE)*	1984 No. (FTE)	Average Annual Growth (%)
Natural	340 (161)	790 (306)	18.9
Agricultural	463 (362)	550 (531)	2.7
Engineering	155 (61)	169 (78)	1.2
Medical	181 (78)	216 (85)	2.3
Social	N/A	638 (212)	--
TOTAL	1139 (662)	2363 (1212)	7.1**

*FTE refers to Full-Time Equivalent researchers. FTE is calculated on the basis of UNESCO recommendations to count three researchers equivalent to one FTE.

**Excluding Social Sciences.

Natural sciences show the highest growth. Excluding social sciences, the average annual growth of all research scientists and engineers was seven percent, which is nearly double the amount of increase in all economically active scientists and engineers (4.0%). This higher rate of increase of research personnel, higher than the rate of increase of all working scientists, is a healthy phenomenon. Growth of R&D expenditure at current prices shows that the level of R&D expenditure has grown considerably although not in proportion with economic activities, as indicated in Table 25.

Table 25: **GROWTH OF R&D EXPENDITURE FROM 1951/52-1983 (RS. 000,000)***

	R&D Expenditure at Current Prices	At Constant Prices	Percent of G.D.P.
1951/52	8.2	8.2	0.17
1959/60	18.8	18.2	0.29
1965/66	19.8	17.6	0.23
1970	21.5	15.6	0.18
1975	45.1	22.7	0.21
1983	162.6	28.9	0.14

*The figures given before 1970 may not be comparable with later ones due to different definitions.

Agricultural research has accounted for a large percentage of the total national R&D expenditure. In 1966, expenditure on agricultural research was 74 percent of the total R&D expenditure. It had dropped to 53 percent in 1975 and 57 percent in 1983. The proportion of capital expenditure also has increased from 22 percent in 1966, 28 percent in 1975 and 37 percent in 1983. The proportion of the recurrent expenditure on personnel emoluments changed from 60 percent in 1966 to 65 percent in 1975 and 44 percent in 1983.

Based on input statistics of expenditure and manpower, a number of input indicators can be developed. The historical trends show that R&D expenditure at constant prices and S&T manpower both have grown steadily. A comparison of R&D expenditure per capita and R&D expenditure as a percentage of GDP are considered as common indicators for comparison of growth in different fields of science. These indicators are given in Table 27.

Table 26: **R & D EXPENDITURE PER RESEARCHER AND AS A PERCENTAGE OF GDP BY FIELD OF SCIENCE FOR 1983/84 (RS. 000)**

	R&D Expenditure per Researcher	R&D Expenditure as a % of GDP
Natural	30.4	0.085
Agricultural	172.1	0.210
Engineering	118.9	0.018
Medical	40.2	0.006
Social	23.0	0.014

Table 27 provides a series of indicators constructed to describe the growth of science and technology in Sri Lanka. The institutional support per researcher is expressed by these indicators.

Table 27: **INPUT GROWTH INDICATORS OF S&T-- 1983 (RS. 000)**

	Equipment	Maintenance per Researcher	R&D Technicians per Researcher
Natural	6.2	5.1	0.37
Agricultural	15.9	33.3	0.44
Engineering.	10.8	23.6	0.25
Medical	2.1	12.5	N/A
Social	0.3	3.6	0.01
TOTAL	7.4	13.3	0.25

To put the Sri Lankan figures in international perspective, it would be useful to work out some international comparisons. In 1980, only 10.6 percent of the total R&D scientists and engineers and six percent of the R&D expenditure in the world were available in developing countries for research and development activities.[15] The average number of R&D scientists and engineers per million population was 2954 for developed countries compared with 125 for developing countries in 1980. R&D expenditure as a percentage of GNP was 2.24 percent in developed countries as against 0.43 percent in developing countries for the same period.

The status of R&D in Sri Lanka in respect to both manpower and expenditure shows us in a poor light. The number of full time equivalent R&D scientists and engineers was 79 per million population in 1984. R&D expenditure as a percentage of gross domestic product was 0.14 percent. Table 28 shows comparative data for selected countries.[16] According to these statistics national financial commitment in Sri Lanka for research and development activities remains at a low level compared to other developing countries such as India, Argentina, Turkey, Brazil, Mauritius and Indonesia. The availability of R&D scientists and engineers per million population is also below most developing countries' averages, and more in the range of countries such as Pakistan, Togo, Thailand, the Philippines and Seychelles.

Table 28: NUMBER OF R&D SCIENTISTS AND ENGINEERS PER MILLION POPULATION AND R&D EXPENDITURE AS A PERCENTAGE OF GNP FOR SELECTED DEVELOPING COUNTRIES

		R&D Expenditure as a % of GNP	Scientists per Million People
Sri Lanka	1983	0.14	79 (1984)
Korea	1982	0.90	723
Argentina	1980	0.50	351
Singapore	1981	0.30	296
Sudan	1978	0.20	219
Mauritius	1982	0.50	176
Indonesia	1982	0.50	113
Philippines	1982	0.20	101
Guyana	1982	0.20	97
India	1982	0.60	89 (1978)
Pakistan	1979	0.20	61 (1981)

Questionnarie C attempted, through structured questions, to isolate some critical factors in R&D as perceived by senior R&D managers and researchers. The result of this exercise was a collection of useful comments, observations and opinions based on the experience of senior scientists and engineers in the country. The responses received were quite diverse depending on the sector they served. Yet, it was possible to extract some common problems through the structured questionnaire.

Questionnaire C received responses from 181 scientific and technical institutions. All major R&D and S&T institutes were among the respondents. R&D activities are primarily distributed among three major areas: agriculture, forestry and fisheries (22%), commerce and industry (36%), and scientific and technical services (15%). The remainder are distributed among the medical services; public utilities such as electricity, gas, water, sanitation and transport; and other public services, such as education, finance, legal services, management and consultancy, computer service and the military.

These institutions have utilized S&T know-how in a variety of ways. Certain institutes felt that the role of science and technology was "vital in all respects" (45%) to carry out their daily functions, whereas 36 percent of the institutions found it only "moderately useful." A small percentage of institutions (3%) found S&T had no significance in conducting their daily activities. (It is worth noting that although the number of major R&D institutions in the country did not exceed a total of 80, a wide array of scientific and technical activities were covered by them.)

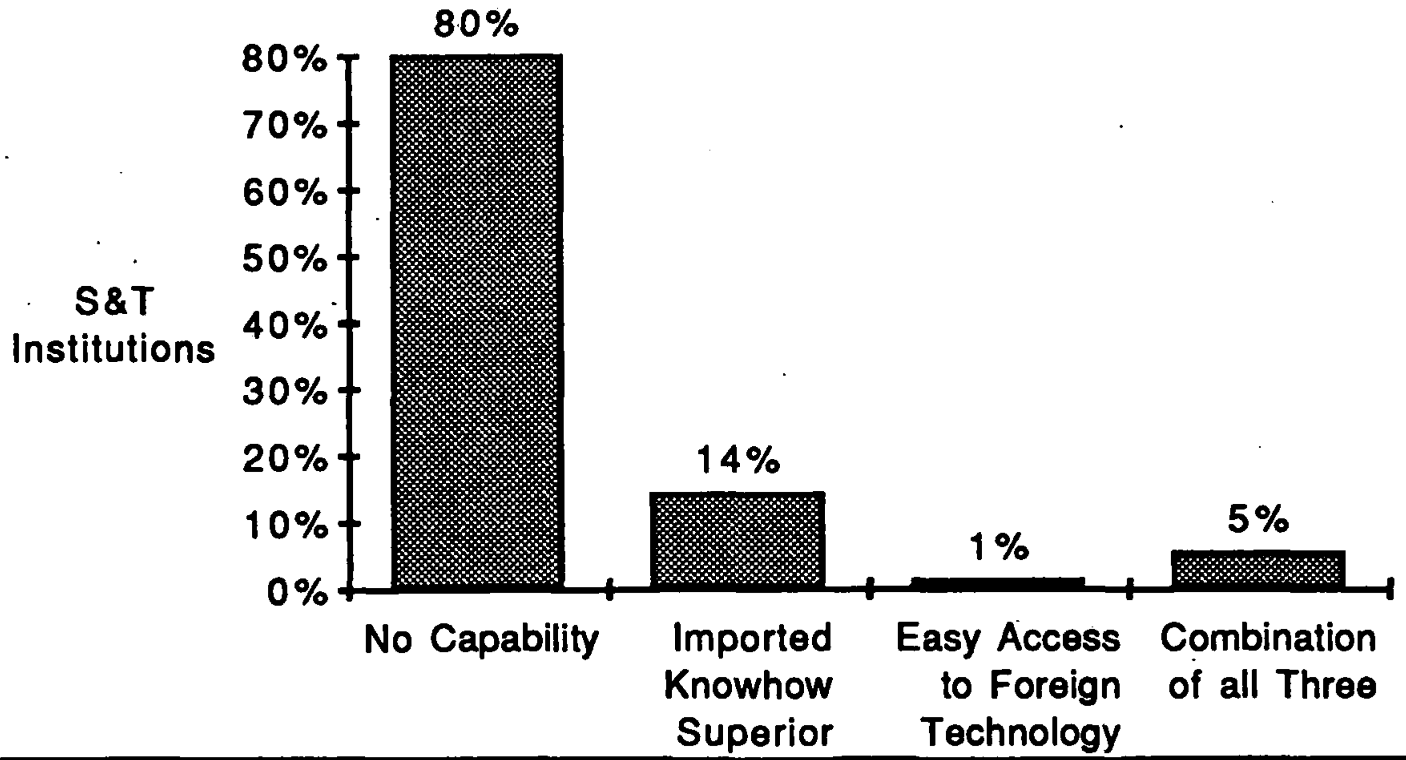
It is also important to note that some major S&T institutions such as the Ceylon Electricity Board, the Irrigation Department, Mahaweli Development Authority, Petroleum Corporation, Geological Survey Department, and Meteorological Department, are not as active in research and development as would be expected judging by the importance and technological nature of these institutions.

A deep-seated tradition of service and production functions in these institutions has apparently suppressed their research and development capabilities. A number of scientists and engineers interviewed in these institutions have identified technical problems that need research-based solutions. However, they are unable to undertake any significant research due to lack of recognition for such activities in the institutions.

A considerable number of these service institutions (14%) gained S&T knowhow via contract research which was carried out in universities and research institutes. This was confined mainly to the field of social sciences. A significant number (14%) depend on overseas sources for S&T knowhow. Others (28%) indicated that they are using a combination of the above three methods (own activities, contract research, borrowed foreign knowhow) to acquire new knowledge.

Fifty-six percent of the surveyed institutions indicated that they depended on foreign S&T knowhow. A large percentage (40%) of the institutions that depended on S&T knowhow from overseas was from the private sector and was involved in industrial and commercial activities. The reasons for this dependency on imported technology are many (Figure 1).

Figure 1: Reasons for Preferring Foreign Knowhow



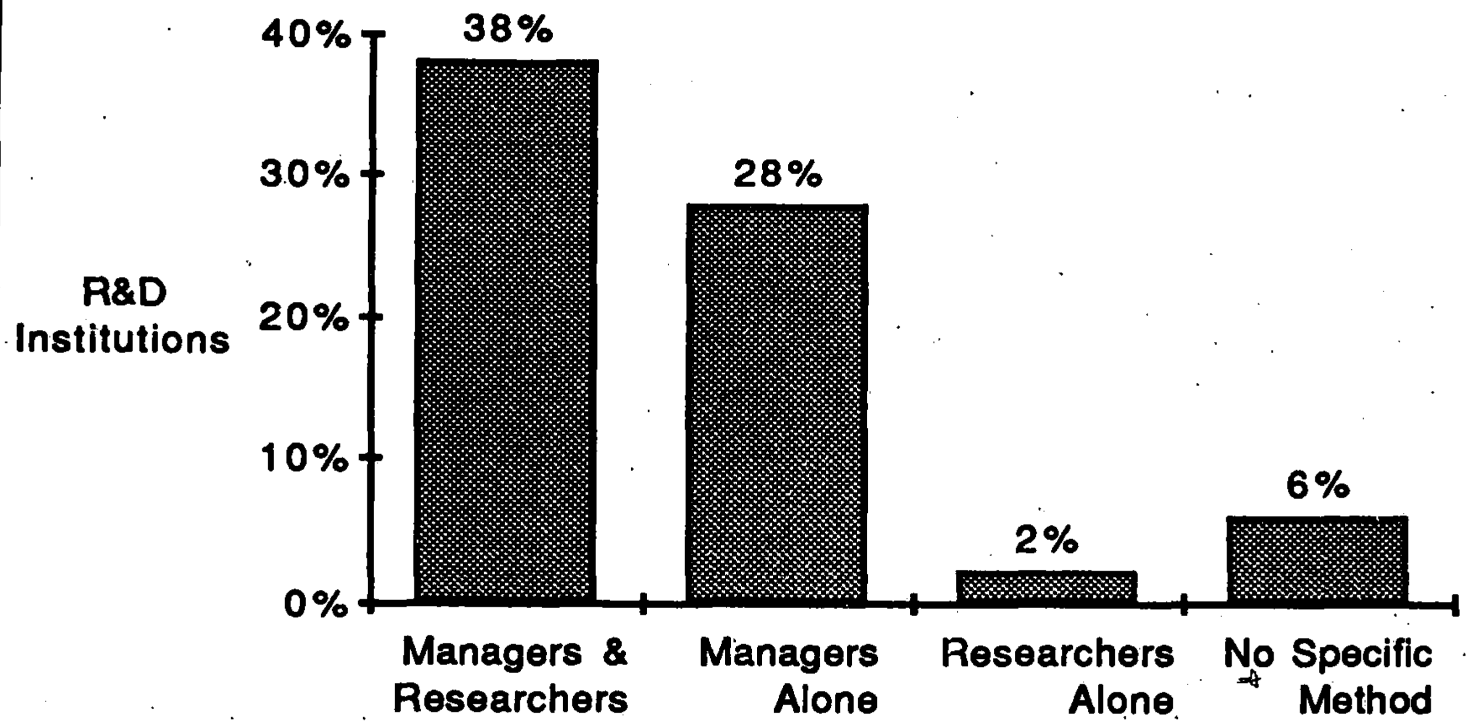
The most important reason was the lack of local capability and expertise to develop needed technologies. It is interesting to note that none of the respondents found competitive pricing of technology as a major reason for preferring foreign S&T, although it was cited by some as a secondary cause.

Fourteen percent preferred overseas technology due to its superior quality. Easy access was the major reason for dependency on foreign technologies in only one percent of the institutions.

A variety of factors influence the project selection process. Significant among these are the availability of finance, urgency of the problem, duration of the project, technical and economic feasibilities and priorities in national development.

Methods of selecting R&D projects vary from institution to institution (Figure 2).

Figure 2: Methods of R&D Project Selection



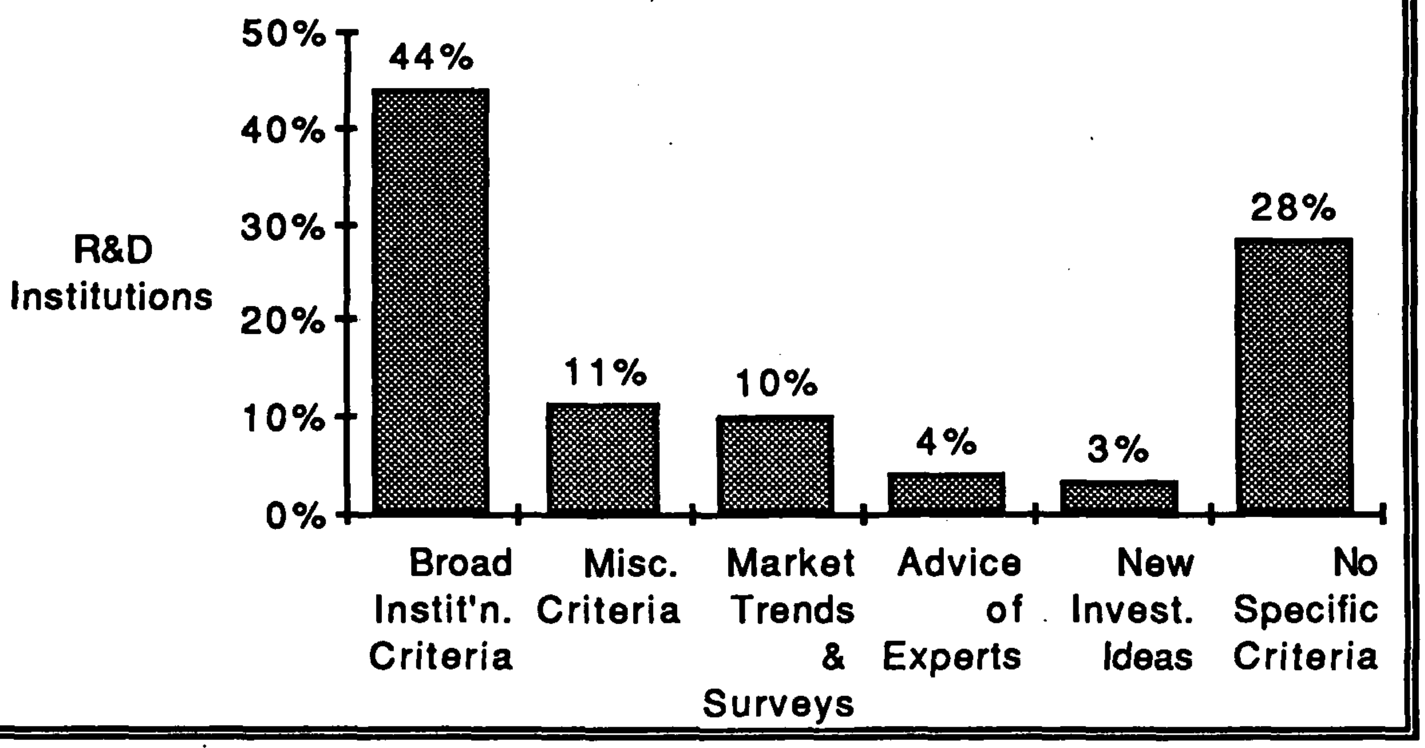
The most common method of R&D project selection (38%) "was partly by management and partly by the individual researchers" themselves. This mode was most prevalent among the major R&D institutes.

It was also not uncommon to find institutes (28% of the total) where project selection was done entirely by the management. In three institutes (2%) project selection was based entirely on the decisions of individual researchers.

Six institutes (6%) did not follow any specific project selection method. Most private industries undertaking R&D had concentrated their efforts in product development, with process development activities undertaken only occasionally.

As Figure 3 shows, the major criteria used for R&D project selection were in accordance with the "broad institutional guidelines" of the institute (44%).

Figure 3: Criteria for R&D Project Selection



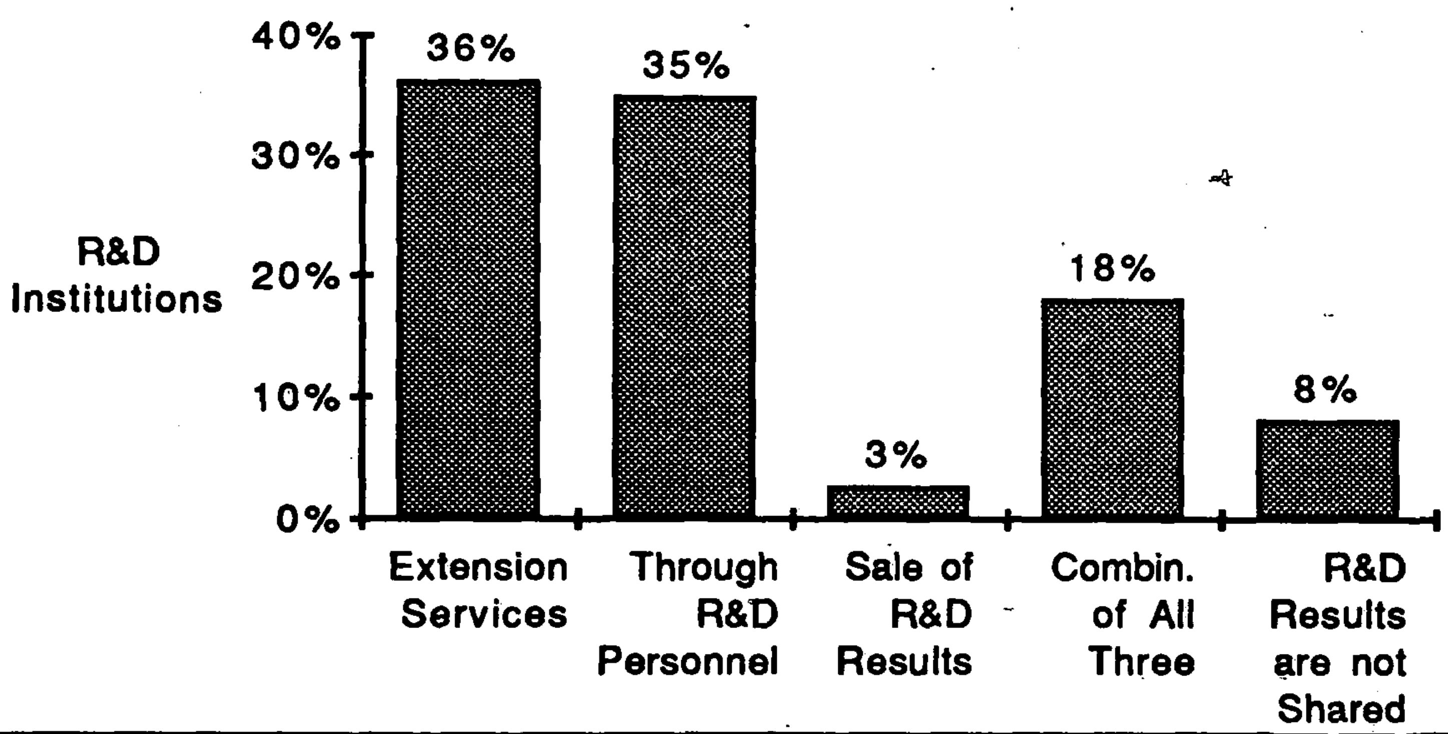
Nearly 10 percent of the institutes, particularly in the production sector, used market trends and surveys as the basis for project selection. A small number of institutes (4%) were solely dependent on the advice of experts in the field being researched. Some institutes (3%) indicated the need for new investment decisions as a criterion for project selection. Twenty eight percent of the institutes indicated that there was no one method used for project selection. In the institutions surveyed, there was a lack of consistency in approach as well as an adequate information base in planning R&D activities, a fact borne out by our interviews.

R&D output should, in the normal chain of events, lead naturally to innovation in industry. Success and failure of innovative projects can be due to several factors. We attempted to isolate some key factors in the failure of innovative projects. The largest number of institutes (25%) identified market failures as a major cause of the failure. This was a common feature in most private sector institutions. Twenty percent of the institutes reported rapid turnover, or the brain-drain of trained personnel, as a major cause for the failures. Another 12 percent reported the most frequent cause as the failure of the R&D process or the technical infeasibility of the project itself. The last two reasons were given most frequently by the research institutes. A small number of institutes blamed the project failure on pilot plant or prototype development problems. Among other responses were poor communication and information flow, lack of coordination and failures in follow-up action.

The questionnaire sought to elicit the major causes inhibiting R&D activities. The reasons cited were inadequate funds (23%), inadequately trained personnel (17%), inadequate equipment and instruments (3%), and a combination of these three factors (24%). A small number of institutes indicated inadequate support facilities and lack of motivation of staff as the major causes. (For example, the Department of Geological Survey had only one trained chemist due to a rapid turnover of personnel. Apparently, this department is on the verge of coming to a complete halt with a large amount of equipment lying idle.)

There are several mechanisms available for the diffusion of knowledge in Sri Lanka. Figure 4 shows the method of diffusion of S&T knowledge from R&D groups to users.

Figure 4: Methods of Transferring New Technologies



A large number of institutes (86) evaluated their R&D work regularly and another 43 evaluated it occasionally. Some institutes have not evaluated their projects at all. The decision to abandon projects, after evaluations, was taken by nearly 50 percent of the institutes surveyed. This is important as it may indicate the effectiveness of the evaluation system. A study done by the General Research Committee of the SLAAS on the output of scientists in Sri Lanka in ten selected disciplines and three selected institutes indicated that the rate of growth of publications was above seven percent per annum.[17] It also brought out the fact that only a few scientists in Sri Lanka were really productive. The study also noted problems related to formation of critical mass in some subjects arising from both an internal and external brain-drain.

The problem of brain-drain in Sri Lanka is important because it governs the entry of personnel in scientific institutions. Although we have recorded a steady increase in scientific personnel, this has to be muted by the fact that there has been an equally steady, perhaps more dramatic, exodus of scientific personnel from Sri Lanka. The figures for brain-drain for selected disciplines are given in Table 29.[18] They show the numbers of trained personnel who left Sri Lanka for employment abroad for each year from 1971 to 1976. These figures are calculated from monthly embarkation cards.

Table 29: TRAINED PERSONNEL WHO LEFT FOR EMPLOYMENT ABROAD

	1971	1972	1973	1974	1975	1976	STotal
Doctors	108	171	238	284	343	110	1254
Engineers	54	113	94	132	498	183	1074
Accountants	23	41	88	97	162	88	499
Teachers (Univ.)	--	15	24	16	54	32	141
Teachers (Other)	82	55	52	74	279	86	628
Lawyers	8	35	13	30	49	25	160
Technicians	--	20	27	243	176	71	537
TOTAL	275	450	536	876	1561	595	4293

In fact, the above figures relate to a period less turbulent than the last couple of years particularly 1983 and 1984. The brain-drain is directly related to remuneration of scientists. Table 30 gives relative remunerations in certain categories of public and private sector employment, in comparison with those of scientists. It is noted that in certain categories of public sector employment, salaries of managers and administrators are very much higher than those of scientific personnel. A quick glance at Table 31 reveals that remuneration structure is anti-intellectual. This position was further explored in a recent article by Siddeck.[19]

Table 30: COMPARATIVE MONTHLY EMOLUMENTS

Scientists	Post	Qualifications	Total Monthly Emoluments
NARA-NARESA	(a) Grade V	A Degree (no experience)	2050 (Tax free)
	(b) Grade III	Post-graduate qualifications	2600 (Tax free)
<u>Scientists</u>			
University	(a) Asst.Lecturer	Degree (no experience)	1977 (Tax free)
	(b) Lecturer	Post-graduate	2400 (Tax free)
	(c) Professor Grade II	Post-graduate degree with experience	4125 (Tax free)
	(d) Professor Grade I	Post-graduate degree with experience	4625 (Tax free)

Table 30 (cont'd)

Scientists	Post	Qualifications	Total Monthly Emoluments
<u>Other</u>			
Private Banks	Trainee Exec.	Degree	5500 (Taxable)
Private Companies	Junior Exec.	SSC/GCE (O.L.) or Graduate	1500 (Taxable)
State Banks	(a) Messengers	JSC or 8th grade	2800 (Tax free) (Equivalent total including loan subsidies, bonus, etc.)
	(b) Junior Executive	SSC/GCE (O.L.) or Graduate	4800 (Tax free) (Equivalent total including loan subsidies,bonus, etc.)
	(c) General Manager	Minimum Academic SSC or GCE (O.L.) qualifications	8600 (Approx.) (Equivalent total including loan subsidies,bonus, etc.)

We have also obtained some comparative figures on brain-drain in the scientific and other sectors. Our impression is that, although there is a heavy drain of scientific and technical personnel to foreign countries, it hardly occurs in the highest paid public sector, namely the banks (and one should add in the administrative sector).

Non-monetary reasons for the brain-drain have been adduced to the professional isolation of scientists. For example, informal interviews with Sri Lankan mathematicians revealed that they had researched in very different areas during their graduate studies. It is here that allowing academics to meet professional colleagues and interact with the "invisible colleges" of their disciplines would be a very useful device for keeping local scientists in Sri Lanka. But, we found in our interviews that the liberal foreign travel policies exist for professionals in some sectors, such as private business. But, there were protracted procedures for scientific personnel, especially from the universities, desiring to meet abroad with foreign counterparts. Lowering these barriers would help decrease the brain-drain and increase productivity. This could have as great an impact as other incentives.

NOTES

1. A considerable literature exists in the developing countries with respect to S&T development. See Herrera (1982) and Goonatilake (1984) for an overview of this subject. Several studies have been conducted on the use of S&T indicators and statistics in (a) the evaluation of research programs in institutions (Irvine & Martin, 1980, and Smith and Karlesky, 1978), (b) the direction and growth of scientific fields (Bud, et al. 1979), and (c) the evaluation of national research programs (MITRE Corporation, 1980; Johnson and Liyanage, 1984). These studies have pointed out some of the difficulties in developing suitable indicators to describe and measure a nation's S&T system and the advantages and limitations of such indicators in formulating S&T policies.

2. Sri Lanka Association for the Advancement of Science was the prime mover in initiating science planning activities and was responsible for the creation of the National Science Council of Sri Lanka.

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5. Cooray, N. (1970), *Government Expenditure on Scientific Research and Development in Ceylon* - Financial Year 1950/51 - 1965/66 CISIR; Colombo.

6. Liyanage, S., Wijesinghe, T. and Anbalagan, W. (1977), *A Survey of the Expenditure of Research and Experimental Development in Sri Lanka,* 1966-1975, NSC, Colombo.

7. UNESCO (1977), *Guide to the Collection of Statistics on Science and Technology,* (ST 77/WS/4), UNESCO, Paris.

8. Based on the latest available census, Statistical Year, 1981, Dept. of Census and Statistics.

9. University Grants Commission (1982), *Basic Statistics on University Education in Sri Lanka,* Division of Planning & Research, UGC, Colombo.

10. See Sri Lanka Accounting Standard No. 11 of the Institute of Chartered Accountants, Sri Lanka.

11. University Grants Commission, *op cit.*

12. For a discussion on this subject, see Johnson, R. and Liyanage, S. (1983), Australian Science and Technology Indicators, Feasibility Study - Higher Education, Department of Science and Technology, Canberra.

13. See Sri Lanka Accounting Standard No. 11 of the Institute of Chartered Accountants, Sri Lanka.

14. Cooray, *op cit.*, and Liyanage (1977), *op cit.*

15. UNESCO, *op cit.*

16. UNESCO (1984). *Statistics on Science and Technology*, UNESCO, Paris.

17. Goonatilake, S. (1984). *Crippled Minds - Exploration into Colonial Culture*, Lake House Bookshop; Colombo.

18. See "Migration of Trained and Skilled Manpower and Unskilled Labour to West Asia, Employment and Manpower Planning Division," Ministry of Plan Implementation, 26.9.78.

19. Siddeck, M.Y.M. (1985), "Remuneration of Scientist in Sri Lanka," *Lanka Guardian*, Vol. 7 (20), pp. 10-12.

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