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ROLE OF R & D ORGANIZATION IN TECHNOLOGY DEVELOPMENT & TRANSFER*

M.M. Qurashi

Pakistan Council of Scientific and Industrial Research, Karachi

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The role of R & D in the technological development and the major issues of project selection and commercialization of R & D results are discussed in detail. The annual turnover of PCSIR processes in commercial production from 1969 to 1985 is found to show an average increase of 11% p.a. in the total turnover. This compares with the corresponding increase in budge of PCSIR.

INTRODUCTION

Technology is the application of knowledge to new ways of doing things. In some rudimentary form it is to be found in the earliest known history of man. Craftsmen of varying degrees of expertise were found in most ancient cultures and the fine points of their art were often passed down the generations on a personal basis from master to apprentice. Technology of course has become a commodity of commerce, and it covers two forms, viz. embodied technology and unembodied technology. Embodied technology generally comprises the finished products, e.g. consumer goods, vehicles and weapons, and the machinery required for their production. On the other hand, unembodied technology embraces the know-how and patent information relating to the manufactured product, as well as technical details of the machinery, equipments, and materials required, as also specific training for manufacturing it. Technology development and transfer involves a composite of four distinct factors, viz. money, equipment, S & T manpower and information, and in each of these the interest of the seller and the buyer of technology are usually at variance with each other.

Technology, in the sense of practical application of invention or discovery, is as old as mankind itself. From the dawn of history, the power of the human group, be it family, tribe or nation, has depended on the strength of its technology: military, industrial, agricultural or organisational. What is new in human history is science-based technology, the conscious application of science or, better, the results of scientific research to the solution of problems. In this context, it as noteworthy that development is a complex social process, which rests in large part upon the internal innovative capabilities of a society; the import of foreign ideas, values and technologies have a major part to play, but few societies in history have developed exclusively on the basis of such imports.

Science is essentially organised knowledge of the physical universe and ultimately leads us to the principles governing its behaviour. As long as one is interested only in determining these laws and studying their predictions, one may properly be said to be pursuing scientific research in the purely academic sense. *Applied research,* however, envisages undertaking a scientific investigation towards a clearly defined material goal, e.g. the production of a stronger material or article, or the development of a new method or process for its production. Of course, the boundary between the two is not rigid and, in the course of an investigation, one may move from pure to applied research and vice-versa.

APPLIED RESEARCH & DEVELOPMENT

Although we may continue for some years to pick the brains of other countries and to develop our industry on the basis of their know-how, the stage is rapidly approaching when we have to discover new processes and to modify existing ones to suit the special conditions of our country. There is thus an imperative need for what can be called *directed research,* i.e., research directed towards the definite aim of using a certain available raw material or of developing a substitute for some product or of improving the quality of a given manufacture or developing a new manufacturing process or improved quality control.

Although the laboratory-scale solution to an applied research problem is the most important step, yet it is only half the story as far as it concerns the discovery of a new usable product or process. The other half lies in the develo-

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pment of the process on a pilot-plant scale, so that the economic and engineering factors involved can be studied on a semi-industrial level. Moreover, it often happens that the very physics or chemistry of a process becomes radically different in going from a laboratory-scale experiment to the full industrial scale. Certain reactions that work very well on the laboratory scale just will not go on the factory level, and vice-versa. In such cases, particularly, the pilot-plant experiments are the scientist's and the industrialist's greatest safeguard against mistaken or superficial assessments of the economic possibilities of a process, because pilot-plant experiments usually envisage small-scale industrial production. When pilot-plant experiments have established the industrial feasibility of a process and have indicated its basic economic breakup, the applied research may be said to have reached its goal.

THE PLACE OF R & D IN TECHNOLOGICAL DEVELOPMENT

Some of the major steps in the planning and execution of a major technological development project (see Fig. 1 (a) are summarized below:-

i) The first stage would be the collection of technical data on the requirement and alternative ways of meeting it, including possibly ab-initio R & D.

ii) The next stage involves a system-analysis study that would lead to a decision on whether to buy the hardware, or go in for indigenous production, or start right at the beginning. These two stages require little expenditure, but need well-trained, experienced and motivated scientific and technical pesonnel, so that correct decisions are taken.

iii) The third stage, in case local development is indicated, involves the preparation of a technical plan, of which the components should be:

a) procurement of technical know-how.

b) training of personnel.

c) indigenous R & D, where necessary.

d) design, development and prototype trials

iv) Finally, actual execution according to plan under (iii).

A Flow-chart for these four stages plus the commercialization and diffusion is shown in Fig 1(b).

The first stages involving preliminary laboratory investigations and general brain-storming are rarely expensive, and should always be encouraged and spread over various institutions, if necessary.

The second and third stages, involving the systems–analysis and preparation of the technical plan for the whole project, are often the crucial ones, and thus must be worked out in full rapport and intimate relationship with the technical infrastructure, industrial growth and other scientific developments in the country. From here on begins a deep commitment of the concerned Government agencies to provide the necessary executive and financial support for the project until completion of the pilot-plant proto-type studies and the testing trials in stage four.

In quite a number of cases, the detailed analysis of stage two will show that it is more economical to acquire the technology without undertaking any R & D, i.e. stages three and four are not required. However, even for such "technology transfer" a considerable R & D base may be needed for either adapting or un-packing the technology package, so that the technology can truly take root after transfer.

In case it is decided to undertake a sizeable local R & D effort, then stage three assumes crucial importance, because a correct formulation of the technical plan with reference to time, manpower and finances is crucial for the successful execution of the project. These three factors will, of course, depend on the size and impact of the project, the time-span for which may generally lie between one and five years.

AIMS AND OBJECTS OF APPLIED R & D

Applied Research organizations thus have a major role to play in the development of technology in a country. For this purpose, crucial importance attaches to their aims and objects. Accordingly, we consider here some extracts from a typical charter viz. PCSIR:

WHEREAS it is expedient to provide for the establishment of a Pakistan Council of Scientic and Industrial Research to undertake, promote and guide scientific and technological research in respect of problems connected with the establishment and development of industries under conditions prevailing in Pakistan, and to encourage the extension of the results of research to various sectors of the economic development of the country in the best possible manner:

Functions of the Council. The function of the Council shall be:

(a) to set up and manage technological research institutes exclusively for certain selected industries and such laboratories and centres as may be required for the promotion of the overall technological development of the country;

(b) to coordinate and review the work of the institutes, laboratories and centres;

(c) to manage the existing research units of the registered Council pending their absorption in the

Figure 1 (a)

THE PROCESS OF INDUSTRIAL INNOVATION

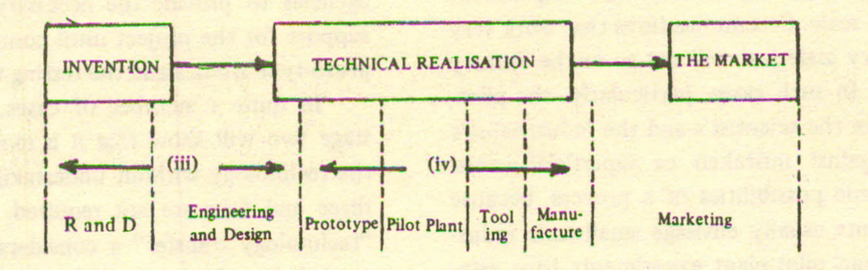
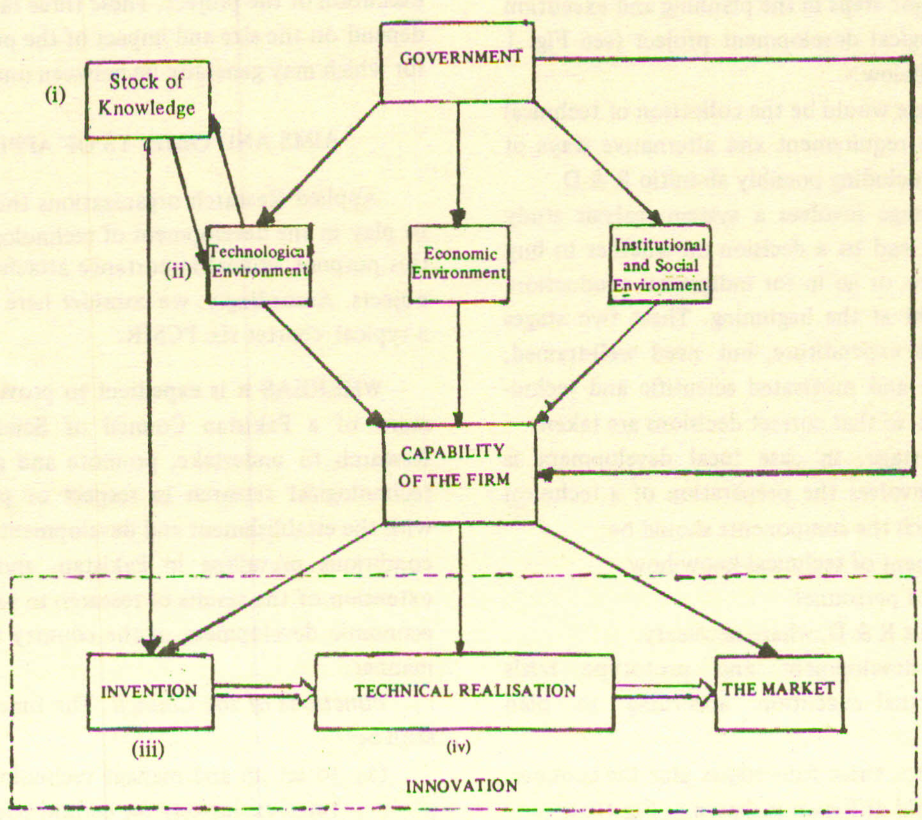


Figure 1 (b)

FACTORS INFLUENCING INNOVATIONS



**(The example of product innovation has been taken, although process innovation is closely analogous)* institutes, laboratories and centres to be set up by the Council; and

(d) to undertake such special scientific and technological surveys and investigations as may be referred to it by the Federal Government from time to time.

In this case, while the aims provide for undertaking, promoting and guiding scientific and technological research related to development of industries as well as extension of the results, the functions tend to concentrate on the setting up, management and coordination of applied R & D Institutes, Laboratories & Centres, with some reference to undertaking relevant surveys. The aspect of technology development, while not specifically mentioned, is of course covered under the aims of extension of results of research.

MAJOR ISSUES

In the case of applied or industrial Research and Development, clearly the end-product is intended to be a viable Technology with well-defined inputs and outputs that are relevant under the conditions set for the country. So, there are a large number of issues that have to be addressed. Some of the crucial ones are:

(i) Selection of projects for R & D,
(ii) Commercialization of R & D results,
(iii) R & D manpower & infrastructure.

Each of these issues involves a multiplicity of parameters that vary from country to country, and which often interact with each other in a complex fashion that can determine the success or failure of the project. In the following sections, we attempt to discuss each of these three uses, rather fully, taking P.C.S.I.R. as an example.

PROJECT SELECTION

The selection of the project stems as much from the local or national priorities as from the constraints imposed by international technological development and its availability, or otherwise. It is in essence a socio-economic analysis, weighing, on the one hand, the fulfillment of social and economic goals set by the nation and on the other, the technological and economic impact of the innovation likely to result from the R & D project being undertaken. In many cases, the two criteria will go together and lead to a unique solution. In case there is a serious mis-match between these two, as often happens in developing countries, the project is not likely to prove effective, even though it may come up with a technologically viable solution. Let us now take a close look at the mechanics of project selection.

This matter needs careful examination because of the frequent conflict between technology development and economic development. In general, there are two ways of going about the selection of R & D projects. One is to take the problems either (i) as seen by Industry itself, or (ii) as defined under the national objectives in the 5-year plans of the Government, and then tailor the R & D programme in accordance with these. While admirable in theory, it often turns out in practice that reliance on (i) leads to very short-term projects with excessive leaning on technology import, while using (ii) as a base leads to programmes that have an evanescent popularity, which disappears when political fashions change, thus leading to *lack of long-term stability* in the R & D programmes. Therefore, one has to make considerable utilization of the *alternate method* of project selection by the scientists themselves, on the basis of their knowledge of the present state of the S & T expertise and an intelligently inspired guess of the future possibilities. The scientist thus plans and lays out an R & D project, which would be based on utilization of indigenous resources but would come up with either an entirely new concept or at least a new and vastly improved version of an existing technology. The R & D work of this sort is usually not very costly (corresponding to item (iii) in the chart of Fig. 1) and quite a lot of it *should be undertaken* if the sources of innovation and invention are to be kept productively flowing.

In fact, the R & D planners' real task should be to arrange a happy and fruitful blend of the two methods described above, so as to maintain a continuing flow of new processes and developed technologies that are in consonance with the rapid pace set by the developed countries, otherwise we run the risk of lagging behind so much as to be forced into a continuing state of technology buying, towards which industrialists and Governmental planners in developing countries are *always inclined* due to a variety of reasons. To counteract this tendency, the developing countries need (a) to emphasize and insert these scientific inputs into the Planning process very urgently, and (b) to plan for a sizable component of *long-range research* in their industrial R & D plans and programmes.

COMMERCIALIZATION OF THE RESULTS OF R&D

The R & D projects reaching completion fall into two major categories, viz. (a) those that are sponsored or otherwise have a user linked or lined up at a fairly early stage of the R & D, and (b) those for which a user is likely to be available but has to be found or selected. It is here that the competition with imported technology of turn-key projects becomes really acute and often operates to the dis-advantage of the local R & D Organizations. To overcome this, an active Pilot Plant or Technology Development Wing and a well-organized Industrial Liaison Wing are essential. The Pilot-Plant studies serve to provide reliable data not only for the economics of the process but also for the up-scaling and design of commercial units, while the Industrial Liaison serves to canvas and convince the Industrialists of the long-term and short-term advantages of the locally developed processes.

During the second decade of its existence (1963-73) PCSIR passed through a difficult phase mainly due to the tight budgetary position especially after 1965, when funds for actual research averaged around 6 per cent of the total budget of the PCISR. Despite poor allocation and lack of experience in research planning and utilization, the PCSIR was able to achieve fairly good results. As early as 1968, PCISR had successfully developed and commercialised over 100 small to medium-scale processes not requiring high levels of technological skills. According to a survey in 1974, the annual turn-over of these processes (defence oriented projects not included) has been around Rs. 33 million.

ESTIMATED ANNUAL TURN OVER

The first estimates of annual turnover of the processes developed and leased out by PCISR was made by A.H. Chotani [1] in 1969 and indicated a turnover of Rs. 20 million per annum for a total of 110 processes. A more detailed analysis was attempted by M. Aslam [2] in 1973-74, the salient features of which are described below.

Four typical case-studies were prepared in which *PCSIR* was involved:

(a) in developing industrial process know-how and indigenous technology.

(b) in developing process know-how, but technology was imported. The results of these case studies are summarized here.

In the first category the cases of (1) Foaming agent (foam concrete), fire-fighting foam, and (2) manufacture of pigments were analyzed. These two industries had in 1974 an annual turn-over of almost Rs. 10 lakhs and were responsible for generating a new technology of foam concrete, which then had a turn-over of around Rs. 30 lakhs/annum.

In the second category, the cases of (1) Paper Cones and Bobbins for textile industries, and (2) Bakelite Moulding Powder were studied. Total sale of textile cones and bobbins since 1967 is Rs. 12,271,000. These two industries were found to have an annual turn-over of around Rs. 30 lakhs.

Selection of these industries for case-studies was not done on the basis that they represent the best examples, but due to the fact that the entrepreneurs cooperated in these cases by providing information needed for the preparation of case studies which they were willing to confirm in writing.

We may now estimate the probable output of the 134 Industrial processes in production in 1973-1974. These processes may be categorised as follows in Table 1.

On this basis, the total estimated annual turnover of the 134 processes works out to around Rs. 33 millions, which compares with the total research expenditure of Rs. 101 million up to 1974. Again in 1983, M. Aslam [3] estimated the turnover of the PCSIR processes then in production as being Rs. 50 to 60 million per annum. As a follow up on this, the Pilot-Plant and Industrial Liaison Directorates in the Head Office undertook a survey of the processes and found that about 35% of the total leased out are actually in production in Karachi and Lahore. This survey leads to an estimated annual turnover of Rs. 155 ± 25 million for the 120 ± 15 processes currently in production in 1985.

These various estimates are collected together in Table 2 and plotted semi-logarithmically versus the year in the lower half of Fig. 2.

A good straight line can be drawn through the plotted points and its slope indicates a mean increase of this turnover at the rate of 11% per annum, corresponding to a doubling every six years or so. This is inspite of the fact

Table 1

Catorgory of Process	No:	Mean Turnover	Total (Million)
A – PCSIR process know-how and technology	74	Rs. 0.3 Million	22.2
B – PCSIR process know-how but imported technology	10	Rs. 0.8 Million	8.0
C Small-scale processes with no Tech. Problems	50	Rs. 0.06 Million	3.0

Table 2

Year	1969	1974	1983	1985
No. of Processes in Production	110	134	–	120 ± 15
Annual turnover (Million Rs.)	20	33	55 ± 5	155 ± 25

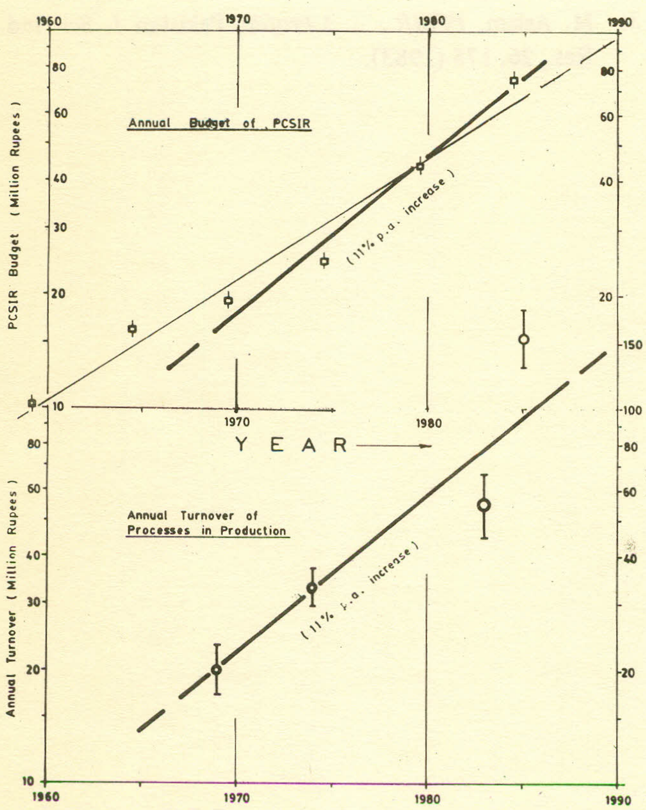


Fig. 2.

that the total number of processes in production has remained more or less constant, between 100 and 135, old processes having dropped out and new ones came in. Some of the processes were purposely kept dormant by the industrialists so as to make other uses of the facilities obtained against these.

In the top half of Fig. 2 is shown for comparison a corresponding plot of the annual budge of PCSIR and, in the period 1969 to 1985, this too is seen to have increased at 11% p.a. on the average, as shown by the thick straight line through the points. So, it runs parallel to the budgets.

DISCUSSION AND RECOMMENDATIONS

In fact the turn-over was consistently about 1.2 times the budget. From this comparison, we may conclude that the so-called "industrial impact" can be considered to be directly proportional to the budget, regardless of the changed policy that was instituted in the early 1970's to stop taking patents and give up doing long-range R & D. The only visible effect of this (perhaps misplaced) emphasis has been to diminish or cut off the main source of real research motivation.

We may summarize here some of the positive recommendations that emerge from the foregoing data and discussion:

1. One of the most urgent needs is, on the one hand, the creation of an efficient and sustained linkage of R & D Institutes with Industry and, on the other hand, the curbing of indiscriminate import of technology, so that the local R & D capability for development of technolgy which appears promising, can be fully utilized. For this purpose (a) a National Code of Conduct for Technology Transfer should be developed and (b) the Inter-Ministerial Import Substitution Committee proposed in the S & T Policy to encourage import substitution, technology development, etc., should be activated as early as possible.

2. The next important requirement is the preparation and implementation of an adequate long-range R, D & D programme geared to our industries' future needs, as seen in the World-wide context of new technologies. Without such a programme, the role of an R & D Organization would be reduced to just product substitution and trouble-shooting. To quote, "If the fundamental scientific research of a country is poor or weak, (then) applied sciences, industrial and agricultural technologies become stagnant, deteriorate or disappear" – Dr. Bernardo Houssay (N.L), of the Institute for Biology and Experimental Medicine, Buenos Aires.

3. It follows that for proper long-term benefits and planning, adequate S & T inputs must be ensured into the National Planning process, which is at the moment operated almost entirely by economists, mostly in isolation from modern Science & Technology. This tends to perpetuate our state of dependence on technology imports, which cannot be remedied without an effective dialogue between economists and scientists.

4. In order to transform the results of R & D rapidly into Technologies, a Technology Research Development Corporation should be set up, which could undertake the development of promising R & D processes into economically viable technologies that can be profitably undertaken by providing risk funds to prospective entrepreneurs.

5. Since the local industries have basically strong links with the Ministries of Production, Industries and Commerce, therefore active follow-up action in the field of import substitution, technology Transfer as well as in the implementation of developed technologies, is essential by

the Ministry of S & T, in order to accelerate the forward movement towards self-reliance in technology.

6. In the absence of such a positive approach, the applied R & D institutions attached to the S & T Ministry are apt to be cut off from their "consumers" and may justifiably ask to be re-located with the "consumer Ministries" for more effective utilization of results of their R & D efforts.

Immediate action on at least the first four of these recommendations may be considered a sine qua non for the development of technology and the conversion of R & D results into useful technologies in Pakistan.

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