

## ACQUISITION AND DEVELOPMENT OF TECHNOLOGY THE INDIAN EXPERIENCE

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### THE IMPETUS

Technology, in the sense of knowledge organized to do a task has always played major role in economics and social activity. Indeed the material levels of living the character of social and cultural life, and the security of societies have always been closely related to the technologies they used. But the occurrence of the Industrial Revolution first in Britain, its spread to other parts of Europe, and then to the USA, Japan and the USSR, led to Technology coming to occupy centre stage in the development of nations.

2. It was not surprising therefore that the technological backwardness in which colonial rule had consciously kept what are today called the Developing Countries, should have been a key concern, if not obsession, of the leaders of the independence movements of our countries. Whether it was Soekarno, Nehru or Mao Nkrumah or Naseer, they all voiced their concern for rapid technological advancement of their countries as one of the cornerstones of both the fight for freedom and of the nation building task thereafter.

3. Underlying this view was the conviction, based to some extent on history, that what distinguished a poor country from a rich one, a strong country from a weak one, was "modern" technology. At the same time, there was the associated stream of historical analysis of how dominantly agrarian societies transformed themselves into industrial societies, from societies based on subsistence agriculture to high productivity agriculture, all of which led to the spotlight being put on industrialization. The combination of these two streams of appreciation led to focusing on industrial technology in the economic development of the newly independent, poor countries of the world. Consequently from the time they came to acquire political independence (1940's for the first group, 1950 for the second and the 1960's for most of the rest) the poor countries of Asia and Africa set out to industrialize themselves drawing on industrial technologies from the highly industrialized and rich countries.

4. In India, this recognition of the role of Technology in Development and the commitment to its acquisition, development and use, was first enunciated, and has since been enshrined, in the Scientific Policy Resolution (SPR) of 1958. The SPR<sup>1</sup> drafted by Nehru and approved by Parliament states in its opening paragraph:

"The key to national prosperity, apart from the spirit of the people, lies, in the modern age, in the effective combination of three factors – technology, raw materials and capital, **of which the first is perhaps the most important**, since the creation and adoption of new scientific techniques can, in fact, make up for deficiency in natural resources, and reduce the demands on capital." (emphasis added).

In 1983, the Government enunciated a Technology Policy Statement<sup>2</sup> which deal with Technology very comprehensively. More recently, the Government has announced an S&T Policy 2003.<sup>3</sup>

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X (X) Komaravolu Chandrasekhara  
ETH

### THE EARLY YEARS

5. The international climate at the time viz the 1950's, when the first group of development countries (Indonesia, India, China, Egypt), launched on "The Great Ascent" to improve the levels of living of their people, was one in which the highly industrialised countries started providing developing countries, what has since come to be called "economic aid" and "technical assistance". With economists calling for such "transfer of resources" from the rich to the poor, the process of acquisition of industrial technology also came to be called "transfer of technology". However, as we shall see later, this terminology was misleading if not actually incorrect.

6. With the developing countries having little or no industrial infrastructure, let alone industrial productive capacity, the first "transfers of technology" took the form of the supply of complete factories and industrial plants by a "Northern" country to a "Southern" country. The actual actors involved in the process of "transfer" at the working level were a commercial enterprise in a highly industrialised country and a commercial enterprise in a developing country. Typically, a cement plant or a chemical plant was transferred by the supplier sending its production equipment to the developing country, installing and commissioning it, and then training technical personnel of the purchaser to operate and maintain the plant. The skill formation component was realised by supplying the requisite knowledge through technical documents (often called "know-how") and through "hands-on" training, both at the supplier's own plant and at the purchaser's new plant (often called "show-how"). However, in some cases local skills to even operate and maintain the plant were not available, in either the requisite quantity or quality. In such cases, the supplier's technical personnel themselves operated and maintained the plant for quite some time, before local technical personnel were able to "take over" the plant. Such transfers came to be called "turn-key" transfers of technology, as the supposition was that all that the purchaser had to do was to "turn the key" and the plant would start and operate; he had very little to do himself except provide local logistical and infrastructural support. All the early mining, power, Steel and Chemical Plants in this country which came up during the late 50's and till the mid 60's were set up with "technology transfer" undertaken on this basis. The same was the case in other large developing countries like China, Indonesia or Egypt.

### CROWING AWARENESS OF HIGH COSTS AND OF IN-BUILT DEPENDENCE

7. As experience was gained with operating and maintaining industrial plants, as we built up our secondary and tertiary education systems and started producing personnel with knowledge of modern S&T, and getting these personnel trained in the plants of turn-key/ near turnkey plant suppliers (in both OECD and Comcon countries), as the network of R&D laboratories and engineering design companies which we were fortunate to have set up through the vision of Jawaharlal Nehru came up, and, above all, as we built up our capital goods producing industries, we came to appreciate several technical and commercial realities of Industrial Technology.

8. On the one hand, we came to realise that, in the modern age, Technologies were consciously generated through:

- (a) organised R&D and design engineering,
- (b) innovations made in the course of the production process itself.

The first is often referred to as "Technology from Science", and the second, "Technology from Technology". However, in either case the generation of the technology was undertaken largely, commercially, through the investment of economic resources by the technology supplying companies. Gradually, it also became clear that the governments of the technology supplying were also playing a large part in the technology generation and utilisation process through a number of mechanisms from direct financing of enterprises, to assured purchases of the final product, to protection from foreign competition etc. This appreciation led to the recognition that, technologies in general, and industrial technologies in particular, constituted commercial commodities carrying constituted a commercial transaction. Hence one should really speak of "Technology Transactions" rather than of "Technology transfers". There are no "free lunches" in the realm of technology any more than in any other area of commerce.

9. This in turn led to a recognition that there was an international market for Technology like for any other transacted commodity, with its own dynamics of supply and demand. However, this market, the

experience of many developing countries indicated, differed significantly from the market for say agricultural commodities, minerals manufactured products, or capital goods; indeed it was unique in many ways.

10. Firstly, there were no "standard" prices for Know How Packages unlike for say cement or tractors. Therefore, it is a market in which prices depend much more heavily on the degree of competition that was available or could be generated by a buyer than in the case of goods e.g. consumer goods or capital goods.

11. Secondly, that information of all types - on the number and quality of alternative suppliers, on their respective financial position at the time a technology purchase was being contemplated, of their track record of performance in similar technology transactions in other countries or with other buyers in the past - has a profound effect on the buyer's options, on his negotiating leverage and on the price and other terms of the final technology purchase, but such information was extremely hard to come by, indeed was kept as secret as possible by the technology seller.

12. Thirdly, that sellers tried to impose numerous restrictive conditions in the agreements governing technology transactions; restriction relating to the buyer purchasing capital goods or components and parts only from/through the seller, which normally meant the seller charging much more than the open market price for these; restrictions on exports, restrictions by way of demanding a minimum quantum of payments irrespective of the volume of production by the buyer; restrictions on the buyer modifying or even improving the technology purchased. There were, in addition, many restrictive provisions relating to taxation, rights and obligations of the buyer, laws and adjudicatory bodies under which disputes between buyer and seller would be settled, etc.

13. Fourthly, buyers also found that the seller often palmed off on them *obsolete technologies* which the seller himself was in the process of discontinuing use of in his own plant, because he had developed a newer, more efficient technology. This resulted in the cost, quality and other characteristics of the product produced by the buyer being worse than those of the seller, right from the time the technology was purchased. Apart from being deleterious to the domestic economy of the buyer, this obsolescence tended to build non-competitiveness in the international market into the production structure of the buyer right from the beginning, thereby affecting the export performance of developing countries.

14. All these, developing country governments and enterprises found, were loaded against them, due to the "gap" in knowledge and practical industrial experience in allied technologies or areas of industry; "gap" in terms of experience in negotiating agreements for technology purchase and the "gap" of economic and political power, not only of the technology selling enterprises, but of the governments of the countries to which those commercial sellers belonged, whether these were of the OECD or of the

#### COMECON

15. By around 1970, i.e. after about 15 years of experience of the process by developing countries, a major new dimension of technology transactions became increasingly clear. This was the role of Trans National Corporations (TNCs) in these transactions. The setting up by TNCs of wholly owned subsidiaries in many developing countries, and joint ventures with local firms in other cases, injected the element of *ownership by foreign entities* of the plants in which the "transferred" technology was being put to use. What is more, increasingly those plants were being pulled into a global network of subsidiaries of the so-called "mother" company of the TNC headquartered in a highly industrialised country. As a result, the plant in the developing country began to be controlled "extra-territorially", bringing back all the exploitative relationships of foreign companies in colonial times. With this "globalisation" of industry, came the phenomenon of "transfer pricing" between constituent units of the same TNC whether these be wholly owned subsidiaries or joint ventures, thereby greatly increasing the costs of technology purchases to the developing countries<sup>3</sup>. This added yet another dimension to the critical issues of costs of technology purchase viz. the dimension of developing country governments having to pay what are essentially "intra-firm" payments, without the legitimacy and appropriateness of those payments being assessable or testable against any competing prices.

16. Finally, there was the high cost of international technology transactions to the developing country buyers. Various studies undertaken by the United Nations Conference on Trade & Development (UNCTAD) indicated that over the last 15 years,<sup>4</sup> the developing countries had made identifiable and measurable payments - and that too in precious foreign exchange - of \$ 0.61 billion for their foreign

technology purchases in 1970 - a figure which has one up to \$ 2.62 billion per year by 1980<sup>5</sup> and was estimated to be around \$ 9 billion in 1985. The 1980 figure constituted 5% of the total export earnings of non-OPEC developing countries, while it had become 7% in 1985. However, even these large amounts did not capture all forms of technology payments. For example, the data in regard to payments for components and parts, and primary and intermediate materials above their "fair" competitive market price, were known to be substantial, but data identification and collection limitations prevented their quantification.

17. As a result of realising - if slowly - these characteristics of international technology transactions, developing countries came to recognise that such transactions had varying degrees of "technological dependence" built into them. This realisation, in turn, led to a concern for acquiring at least some degree of "technological self reliance".

18. If one were to distill a set of Aphorisms - may be they are slogans - on the issue of dependence vs. self-reliance, they would look like this:

Point

INDUSTRIALISED NATIONS ARE AN "S&T SUPERMARKET" FOR DEVELOPING NATIONS

Counterpoint

"GOODS" (TECHNOLOGIES) IN THAT "SUPERMARKET" COME WITH STRINGS AND AT EXHORBITANT PRICES

ATTACHED

Point

DEVELOPING COUNTRIES HAVE 'THE BENEFITS OF BEING LATE-COMERS' IN S&T

Counterpoint

LEARNING FROM YOUR OWN MISTAKES AFFORDS GREATER BENEFITS

Point

DON'T RE-INVENT THE WHEEL (BUY FROM THE "SUPERMARKET")

Counterpoint

LEARNING BY DOING IS ESSENTIAL FOR LOCALLY ROOTED DEVELOPMENT

#### UNBUNDLING THE TECHNOLOGY PACKAGE<sup>7</sup>

19. But coming to practicalities, how does one acquire such technological self reliance? By the early 1970's studies and actual experience of the content of technology transferred revealed that industrial technology was not a "black box"; that it had a structure with a number of constituent elements, the most important of which were:

- (a) Documented Knowledge (DK)
- (b) Skills (S)
- (c) Hardware/Machinery (H)

Experience showed that technology was partly disembodied (DK), partly embodied in hardware (H) i.e. machinery or capital goods, and partly embodied in human skills (S). While DK, often loosely termed "Know How", was often regarded as the core of the technology, operationally it was meaningless to speak of "transfer of technology" without dealing with the other two main elements viz. H and S. The relative contributions of these three components varied widely from technology to technology i.e. from production process to production process. They also varied in the same production process over time, due both to the demands of the market and to the relative costs of labour and capital.

<sup>7</sup> This and the next three sections draw heavily on a paper by Ignacy Sachs, *Economic & Political Weekly*, Bombay, Vol. V, Nos. 29-31, Special Number, July 1970.

## DEPENDENCE AND SELF-RELIANCE

20. If we use the subscript  $d$  for domestic and  $f$  for imported/foreign, the matrix of the possible situations is the following one:

- (a)  $S_fDK_fH_f$  : Foreign specialists apply a foreign invented technology and operate imported equipment (Turn Key Plant).
- (b)  $S_dDK_fD_f$  : Local manpower works with foreign know how, using imported equipment.
- (c)  $S_dDK_d$  : Equipment has been imported for domestically developed know how put into operational use by local manpower.
- (d)  $S_dDK_dH_d$  : Using foreign know how, local manpower undertakes production using locally produced equipment.
- (e)  $S_dDK_dH_d$  : All three elements are local.

From the viewpoint of the degree of technological dependence, or contrariwise, self reliance, involved in the particular technology transaction, Case (a) is obviously one of total technological dependence while Case (e) is one of total self reliance, while the intervening cases reflect varying degrees and forms of technological dependence.

21. Such a matrix can be used to analyse the degree of technological dependence of a country in many ways and from different perspectives:

- (i) as a "snap shot" of the state of technology in different sectors of industry at a given point of time.
- (ii) as a "dynamic flow chart" of the way in which the technological level/status of the industrial economy as a whole has evolved over time - Case (a) being the point of departure at time  $t_1$  in the past and the subsequent cases the status at later points of time.
- (iii) as a "dynamic flow chart" of a sector of the industrial economy evolving over time.
- (iv) both a "snap shot" and a "dynamic flow chart" of a particular company or organisation.

22. The matrix does not imply, however, that reaching  $S_dDK_dH_d$  in all sectors of the industrial economy and/or in all enterprises in a particular sector, should necessarily be the goal of either technological development strategy or economic development strategy. The planner, whether at the national or macro level or the company or micro level, has considerable freedom of choice. In many lines of production, the planner might opt for Case (a), as a long term solution. But in others, he would feel the need or compulsion to opt for Case (c). In such cases, he would need to decide which of (b) (c) or (d) is the appropriate initial goal to strive for, which one would be the next goal and so on. In other words, what the exact route should be to go from state (a) to state (e) in that particular technology.

## NEED FOR STRATEGIES FOR TECHNOLOGICAL DEVELOPMENT - NOT MERE "TRANSFERS"

23. This analytical framework came to be increasingly widely elaborated in the early 1970's as a result of several studies by UNCTAD, and by radical economists and S&T policy analysts, particularly in Latin America, in this country and in some S&T policy Research Institutes in the UK. As knowledge of it diffused through the developing countries, the United Nations System, and some of the more liberal industrialised countries, it became clear that "technology transactions of transfer" was only one component of the much larger issue of "Strategies and Policies for Technological Development of the Developing Countries". Such a strategy needed to spell out fairly precisely, priorities - at the national, sectoral and enterprises levels - the paths or routes to be followed for the technological development process, the organisational and managerial structures needed to deal with S, DK and H, and, most importantly to inter-link them, and the time scheduling of the operations. Of course, this task had to be undertaken taking into account the character and goals of the overall industrial strategy of the developing country concerned, on the one hand, and on the other, the capacity of the systems in the country responsible for generating or producing S, DK and H. These were:

- For S : The Educational System  
 DK : The R&D laboratory and engineering design company or design bureau systems  
 and H : The Industrial or more especially the machinery manufacturing or capital goods producing system.

#### ADAPTATION & ABSORPTION

24. If technological dependence is to be minimised if not avoided as an integral objective of a strategy of technological development, and if self reliance is to be advanced, it is extremely important to recognise, that an imported DK may serve as an input, both for production and for R&D. Of course, in the former case it is immediately used in the production process, whereas in the latter case, it is used as a base for improved/new technology through scientific research in a laboratory or engineering research design bureau. If we keep in mind this double function of the DK acquired as part of imported technology, the transfer process can be made to take one of the following 4 forms, through conscious policy decisions and actions: (Figure - 1)

- (1) Adaptive Transfer
- (2) Full Transfer
- (3) Full Adaptive Transfer
- (4) Pseudo-Transfer

25. If we recall the experience of most developing countries on international technology transactions discussed earlier, it will be seen that "Pseudo-Transfers" are likely to constitute the bulk of such transactions, if the transactions are left to enterprise - to - enterprise decisions and actions, without the intervention by a State which has a defined technology development and utilisation strategy. It is certainly the case of transactions between the principal of a TNC belonging to a highly industrialised country, and its subsidiary/affiliated company in a developing country. Under this type of transfer, an "echo principle" operates in regard to technology imports i.e. every so many years, say 5 years or 8 years, it becomes necessary for the technology buyer in the developing country to purchase the up-dated or new version of the original technology in order to renovate or upgrade its own technology.

In the short run, Pseudo Transfers are the easiest to work out. They also create the comfortable feeling that one is getting access to "The latest technology". But, they ignore the specific conditions of the importing developing country. Furthermore, they perpetuate a situation of complete technological dependence, not to speak of the burden which the payments for technology under such forms of transfer place on the country's foreign exchange resources.

26. Using the above categories, it is easy to construct a scale of preference for the modes of acquiring technologies and inducting them into the production system:

- Autonomous Effort/i.e. Domestic technology Generation
- Full Adaptive Transfer
- Full Transfer
- Adaptive Transfer
- Pseudo Transfer

However, in actual practice, no developing country is in a position even today to mount an R&D effort of such scale, quality and speed as to be able to generate all the technologies it needs, even on a secondary i.e. Adaptive basis, let alone on a primary i.e. Autonomous basis. Nor, perhaps, would it be desirable, whether for the technological development of the country, for its industrial development or for its overall economic development. Therefore, all the 5 modes-including the Pseudo Transfer mode - will have to be employed. What is crucial is:

- (i) to be aware of these different modes, not only at the national planning/policy making level, but at the sectoral level, at the enterprise level, and at the user level.
- (ii) to recognise that there are different types and magnitude of costs and benefits in each of these modes - technical, financial, and political.

- (II) to develop - at the sectoral, enterprise and specific product levels - criteria of choice between these modes for "feeding" a particular production mission with the technology it needs.

27. If we were to take this analysis one stage further in terms of operationalisation, the central issues of policy making for designing an integrated strategy for self reliant technological development, would be:

- (a) what criteria to apply to decide which technology should be imported and which should be generated at home.
- (b) how to build up the 4 systems, viz. Educational, R&D, Design Engineering and Capital Goods production and inter connect them in such ways that the technologies (involving all 3 elements S, DK and H) chosen to be generated at home, are, in fact, so generated, in defined time frames, and with high probabilities of technical and economic success.
- (c) in those cases where it is decided to import the technology, how to integrate that imported technology into the domestic S&T system, so that the domestic technological capacity is strengthened, and not only subsequent import of similar technology is obviated, but locally generated equivalents, if not superiors, generated and utilised. However, there is also the 8-fold path of the Buddha, which has proven its efficacy in the case of many of the industrially more advanced developing countries like ours. The core ingredients of the recipe are <6.
  - (i) setting up a policy making and implementing agency which should, on the one hand, frame a strategy appropriate to the country/ sector concerned; on the second hand control the actual purchases of foreign technology, including the screening of large projects, from the viewpoint of the choice of technology, source of purchase and negotiating support, and on the third hand, develop, through planned funding, indigenous know-how generation, and the linking of that know-how to the S and H elements, promote the putting together of the indigenous technology package, and get it into commercial production, all with the close involvement of the customer or user.
  - (ii) building up, under the auspices of such an agency, a strong Industrial Information system, able to provide public and private companies in the production system of the economy, with independent knowledge on sources of DK and H - and in some case also S both abroad and within the country, thus strengthening the bargaining power of the technology purchasers.
  - (iii) Setting up engineering design and consultancy organisations, particularly in sectors like steel, petroleum, chemicals which are process based industries, which organisations can help to define the plant and equipment design and engineering elements of the total technology package, and use that definition to (a) "unpackage" foreign technology packages and (b) "package" domestic laboratory scale process know how into complete industrial projects.
  - (iv) R\*D laboratories performing a 4-fold function -
    - providing specialised advanced training to S & T personnel coming out of the higher education system.
    - doing applied research, oriented at developing laboratory scale know how.
    - assisting the policy making agency and the enterprises in identifying, selecting and negotiating with foreign technology suppliers to effect the purchase in the most "unpacked form possible
    - and thereafter, participating, with the technology importing enterprise, in the absorption adaptation and further development of the imported DKG - documented know how.

#### DOMESTIC TECHNOLOGY GENERATION AND COMMERCIALISATION

29. I would now like to turn to consider, in some depth, the process of domestic generation of technology and its commercialisation. As touched upon earlier, the commitment of Jawaharlal Nehru to science and scientific thinking led to the building up, from the very early years after Independence, of a capacity for what was termed over the period 1947-1967, "Scientific and technical research". This "Capacity" took the form of setting up a number of research laboratories under the Council of Scientific & Industrial Research (CSIR) as far as the general economy, particularly the Industrial sector of the

economy was concerned. These laboratories were organised on the basis of scientific disciplines e.g. the NPL (for physics) or the NCL (for chemistry) on the basis of sectors of industry e.g. drugs, electronics or aeronautics, and on the basis of addressing the needs of a particular region e.g. the Regional Research laboratories, at Hyderabad, Jammu and Jorhat. This thrust was paralleled with the build up of a similar institutional infrastructure under the Defence R&D Organisation (DRDO) i.e. a set of discipline/sector-based laboratories. However a rather different structure was set up in the area of atomic energy viz. one major R&D centre, but encompassing practically all the areas of science and engineering needed for the atomic energy programme - from biology to physics and metallurgical engineering to electronic engineering. I refer, of course, to what is now known as the Bhabha Atomic Research Centre (BARC), Bombay.

30. The research laboratories of the CSIR and to a lesser extent of the DRDO were originally set up on the premise that the mere assemblage of scientists in laboratories and "letting them loose" to do research on scientific problems of their interest and choice would "automatically" result in contributing to the industrialisation of the country, or to its defence preparedness. Reference was often made in this connection to the statement in the Scientific Policy Resolution (SPR) of 1958 of how "new scientific techniques" could make up for deficiencies in natural resources and reduce the demand for capital - an objective of particular importance in a country like ours which was short of capital. However, hardly any attention was focussed on quoting the SPR fully and correctly in this important respect. What the SPR (now almost 30 years old) had stated was:

"the creation AND ADOPTION of new scientific techniques can, in fact, make up for a deficiency in natural resources, and reduce the demands on capital".<sup>7</sup>

The critical importance of ensuring adoption of the results of R&D was given hardly any intellectual attention, let alone governmental action. As a result, the building up of the industrial capacity of the country proceeded in the period 1955-1970 almost totally on the basis of imported technology, while the "scientific research" capacity was built up largely independently of the nation's industrialisation effort i.e. the Pseudo Transfers discussed earlier. What is more, since the laboratories of the CSIR and the DRDO were staffed at their inception from the only pool of scientific manpower available viz. the universities, the laboratories tended to have far closer interactions with the universities than with industry.

31. Between 1950 and 1970, the nation had invested some Rs. 150 crores\* in the CSIR laboratories and between 1959 & 1970 some Rs. 60 crores had been invested in the DRDO laboratories and questions were rightly being raised as to what tangible economic returns the nation had secured from this investment. Incidentally, investment in CSIR labs over 1970-1985 has been a further Rs. 1000 crores and in DRDO, a further Rs. 1300 crores. The ensuing debate shifted the focus for the first time from "Science" and "Scientific Research" to "Technology and Technological Innovation" as the key issue, even as far as the domestic R&D system was concerned.

32. Technological Innovation may be described as the process by which knowledge on how to produce a product not available in a given market, or how to improve the performance of an existing product, reduce its cost, or market and distribute the product more efficiently, is made a reality. The process of Technological Innovation can be visualised conceptually in terms of "a chain made up of a number of links". This is shown in Figure 2.<sup>8</sup>

### FEATURES OF THE MODEL

33. If we examine this model closely we will see that it has been so structured as to enable each activity in the chain to be associated with (a) the kinds of manpower needed to undertake it (b) the goals such manpower is expected to work towards, and (c) the institutional setting which the work is to be carried out.

Part A covers basic research, undertaken usually in academic institutions and, to some extent, in government laboratories, by scientific staff who are leaders in some specialised field, and aimed, not at making any particular invention, but at the advancement of basic scientific knowledge. Part B spans the

\* 1 crore of rupees (Rs) is 10 million rupees. At the prevailing official exchange rate, this amount has been equivalent to: US 2.5 million over 1947-66 to US \$ 1.5 million over 1967-1979, to US \$ 1 million over 1980-85 to US \$ 0.75 million today.

gap between basic research and engineering design, which we often call Development in the R&D sense. The kind of personnel required here are largely those with scientific backgrounds acquired from participating in A. However, and this is important, it also includes some engineers. The activity undertaken is often as complex as that tackled in Part A but is more directed at producing a new product or processes in a defined time frame. Part C is a stage manned almost completely by engineers whose sole aim is to get products and processes ready for production. The final part D deals with the (supposedly) well understood activity of industrial production, marketing, sales and after-sales service.

#### IMPLICATIONS FOR POLICY MAKING

34. We can draw several important deductions from such an "innovation chain", relevant to policy making:

- (1) Innovation is inextricably concerned with interfaces - technical interfaces, economic interfaces, institutional and behavioural interfaces - and it is on the identification of such interfaces and on ensuring smooth and effective flow of information and action across each of them, that successful innovation largely depends (See Figure - 3)
- (2) The fact that administrative control over each section in the chain frequently lies in the hands of different organisations, makes such interfaces often no-man's lands. This requires that, at least in the early stages of the development of an industry, the innovation process as a whole must be conceived, planned, promoted and coordinated by a single over-riding managerial authority.
- (3) The activities in the chain are, by and large, sequential in occurrence. But, and this is an important proviso, the activities also overlap considerably on all the counts mentioned earlier. They also overlap in terms of time. This provides some scope for undertaking activities in parallel, thereby shortening the total "Innovation lead time".
- (4) Each activity will take a certain minimum amount of time, no matter how large an investment in men and money is made on it. Therefore, the time-phasing of the various activities in the chain plays a crucial role in ensuring that the innovation is successful.
- (5) There is a Resource threshold, in terms of annual outlay on men, equipment and material for each segment of the chain, which must be crossed if the project is to move to the next segment in any finite time interval.
- (6) The magnitude of such critical or threshold level of resources required to complete each activity is far from uniform across the chain. However, in general, it increases as one moves towards the final stages of the chain.
- (7) While the ratio between resource requirements for various stages in the chain will vary from product to product, studies have shown that, in a majority of cases the distribution of costs across the chain is typically as in Figure 4.9
- (8) The kinds of skills and aptitudes which the manpower deployed in each of these stages need to have, vary considerably, particularly in regard to specialisation. The development of manpower must therefore be undertaken keeping in mind the nature of the activity which each type of professional is to be deployed on.

#### CAUSE FOR OUR FAILURE

35. Once the concept of "the innovation chain" came to be accepted in the early 70's, its inherent characteristics were recognised, and the implications for Technology Policy perceived, it became relatively easy to see why the efforts of most CSIR and DRDO laboratories over the previous decade, on an activity loosely called "R&D", were not producing "results" in terms of industrial technology and production, anywhere near those realised using imported technology.

First, while the innovation chain as a concept was known to policy makers in a theoretical way, no attempt had been made to use it in real life decision making up till then. Moreover, at the operational level of managers in industry and project leaders in R & D laboratories - there was lack of awareness of even the existence of such a chain. As a consequence, the fact that interface problems are bound to come up at some stage in the development of what starts off as an R&D project in a laboratory, came, time and again, to be recognised only when the laboratory claimed it had "completed" its task, but no manufacturing unit was willing to undertake commercial production, or the customer/user denies that his needs have been met.

Secondly, the features of the institutional structure available to us at that time for bringing about technological innovation, viz. organisational and managerial separation of the different institutions responsible for various stages in the chain, lack of the most rudimentary information system on needs, production programmes underway, development projects in progress, etc. militated strongly against the essential prerequisites for successful innovation.

Thirdly, much of the success of technological innovation and, more narrowly, of goal-directed R&D, depends critically on our having the ability to make demand forecasts with increasing accuracy. What is more, such demand assessments had to be reduced to product-specific terms if successful technological innovation was to be achieved. Such demand forecasting is difficult, and calls for the use of sophisticated techniques. But the fact that, for a large part of the capital goods sector at least, the government or government companies were and still are the major buyer, should make things much easier. But equally important as having such a forecast at all, was its availability sufficiently far in advance of the time when the product is first needed, to enable not merely R&D but also the remaining stages in the chain to be undertaken in time. In short, the need for planning.

Fourthly, most industrial units, and almost all R&D laboratories, were extremely weak in production engineering capacity, and indeed persons trained in the design, development and engineering of production machinery, jigs, tools and fixtures were woefully small in number. This proved to be a major bottle-neck in ensuring that process know-how or product design, once proven on the laboratory scale i.e. brought up to stage 6 in the innovation chain, was carried forward to the next two stages, viz. engineering of production prototypes and designing and fabricating of equipment enabling volume production.

Fifthly, the very fact that the overwhelming bulk of our industrial production in 1970 was based on imported technology had prevented manufacturers from having to face the difficulties of true technological innovation.

As we saw earlier, under a foreign licence or technology import agreement, the licensor usually provides the following inputs:

- (a) the complement of production equipment needed for the production process.
- (b) detailed plant layout and either written instructions or its own personnel for installing and commissioning production machinery.
- (c) details of production process with blue-prints, production drawings, testing and approving procedures.
- (d) bill of materials for the products covered by the licence.
- (e) training at their plant of our staff who are to supervise production and the testing and control of quality, volume, etc.
- (f) training of workers for various operations through the deputation of one of their plant supervisors or equivalent production operatives to this country; and
- (g) consultancy services to overcome teething troubles.

These inputs correspond only to those related to stages 8, 9 and 11 of the innovation chain. However, this does not mean, of course, that the licensor did not himself go through the earlier stages in the chain, particularly from 4 onwards. But that experience is never communicated in the transfer process, even implicitly. Consequently, when presented with domestic "know-how", which has only come as far as stage 5 or 6, the local manufacturer is reluctant to commit the men, money and intellectual and managerial effort needed for him to learn how these stages are performed. This is particularly so when he is sure that he can continue to rely on packaged technology from abroad on a continuing basis i.e. through what has earlier been called "Pseudo-Transfers".

Over the last 10 years i.e. since 1970, awareness and understanding of these realities of the "Innovation Chain" have been steadily diffusing more and more extensively into most of our R&D agencies, our manufacturing companies and among major customer groups including user agencies in government.

Those who have had any involvement in India's Defence Production and Defence R&D over this period, will, I am sure, agree that DRDO today is very different indeed from what it was in 1970 in terms of planning for and realising successful technology transfer, and commercialisation of a range of military systems and equipment.

From my experience in the Department of Electronics (DOE) over the same period, I can say that this

has certainly been so across a wide front in professional electronics. The Department of Space has built such thinking, planning and action into its R&D Centres right from the inception of the Department in 1972. This is also the case with the Department of Atomic Energy and its domestic technology generation and commercialization or utilization activities, and with several CSIR laboratories.

To cite a few specific examples of successful domestic technological Innovation.

As for DRDO, I would cite the Main Battle Tank, Arjun Mountain Gun, the Special Anti-Tank Ammunition, Low Level Radars the Advanced Panoramic Sonars and a whole range of Electronic Warfare Systems and Missiles as examples of major technologies which have been successfully developed, put through the innovation chain and in various stages of regular production already, or at levels ranging from several tens of crores to several hundreds of crores worth per year. What is more, the whole project or programme in these cases has been undertaken with considerable professionalism and confidence, though not without many agonizing moments.

### **PROFESSIONAL ELECTRONICS, PHARMA, TRACTORS AND AUTOMOBILES**

An illustrative list indigenously developed and successfully commercialized hi-tech electronic systems and equipment, pharmaceutical products, Tractors and Automobile is given in **Annexure I**.

What I think one can say with confidence, now is that in many sectors of industry, including those involving sophisticated technology, we now know what it takes to bring about successful generation and commercialization of indigenously developed technology. Perhaps more importantly, at least in a number of areas, we also know why failures occur, to the point where we can forecast with reasonable accuracy that an incorrectly structured and managed technology development project – particularly one which violates the principles of the “Innovation Chain” – is almost certain to fail. In short that there is a “Technology” of Technology Transfer, calling for specialized analytical, managerial, and behavioral skills on the part of planners and policy makers and technology generators and utilizes.

### **SELF RELIANCE**

The identification and analysis of the key issues focused on here also enables one to arrive at an operational formulation of the concept of Self Reliance in Technology.

This formulation encompasses a number of levels. The first level is that of decision making. Self reliance means that we are in a position to define our own goals – goals which are appropriate to the development strategy and development pattern which the country has chosen. Next that we are able to define the types of technologies we need to realize those goals, and the modes through which such technologies are to be acquired or generated. The second level is that of undertaking, MAKE or BUY choices at the sectoral and enterprise levels, in relation to the specific set of technologies needed for the development of the sector or enterprise concerned. Thirdly, how to identify and select from the foreign technologies available for those products for which the second stage exercise has shown that technology purchase is necessary. Fourthly, self reliance in being able to negotiate effectively to acquire those foreign technologies on the most favorable terms to the buyer. Firstly, self reliance in building up S&T expertise in all key areas of national importance, and in increasing that competence and capacity to the “critical levels” needed for generating technology domestically in the core areas.

Self reliance does not mean building a wall around oneself, it does not mean autarchy, even less, isolationism. But it does mean being “maximally in command” of the whole technological strategy at the national, sectoral, and company or agency levels.

As our late Prime Minister Smt. Indira Gandhi, who did so much to enhance our self reliance in general and I S&T in particular put it:

"Self Reliance means the assertion of our right to formulate our policies, programmes or Institutional mechanisms. We have to make our own choices, taking account of world developments in science and technology but without being swayed by fashions within science, or the S&T foreign policies followed by advanced countries".<sup>12</sup>

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Figure 1

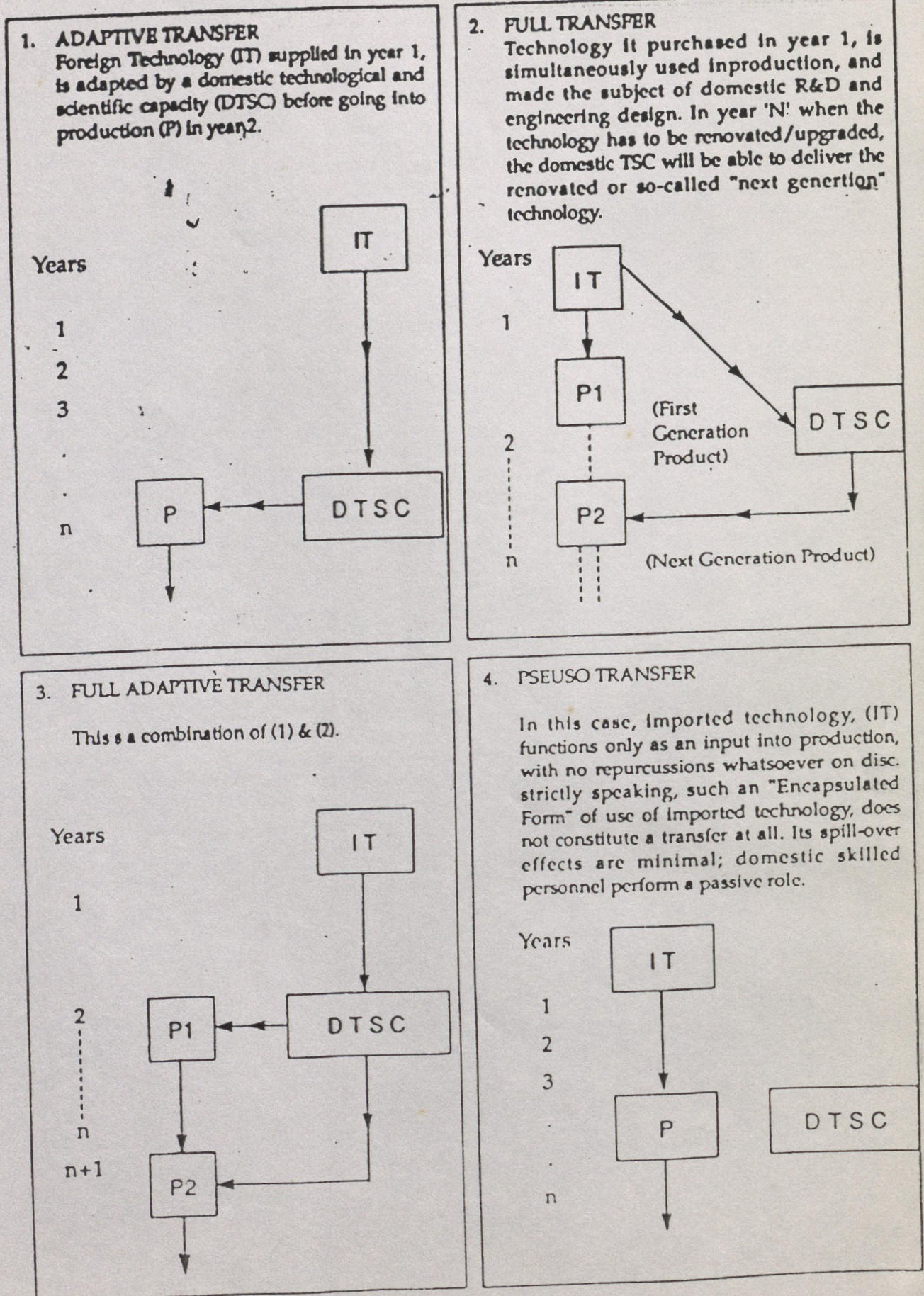


FIGURE - 2

THE INNOVATION CHAIN

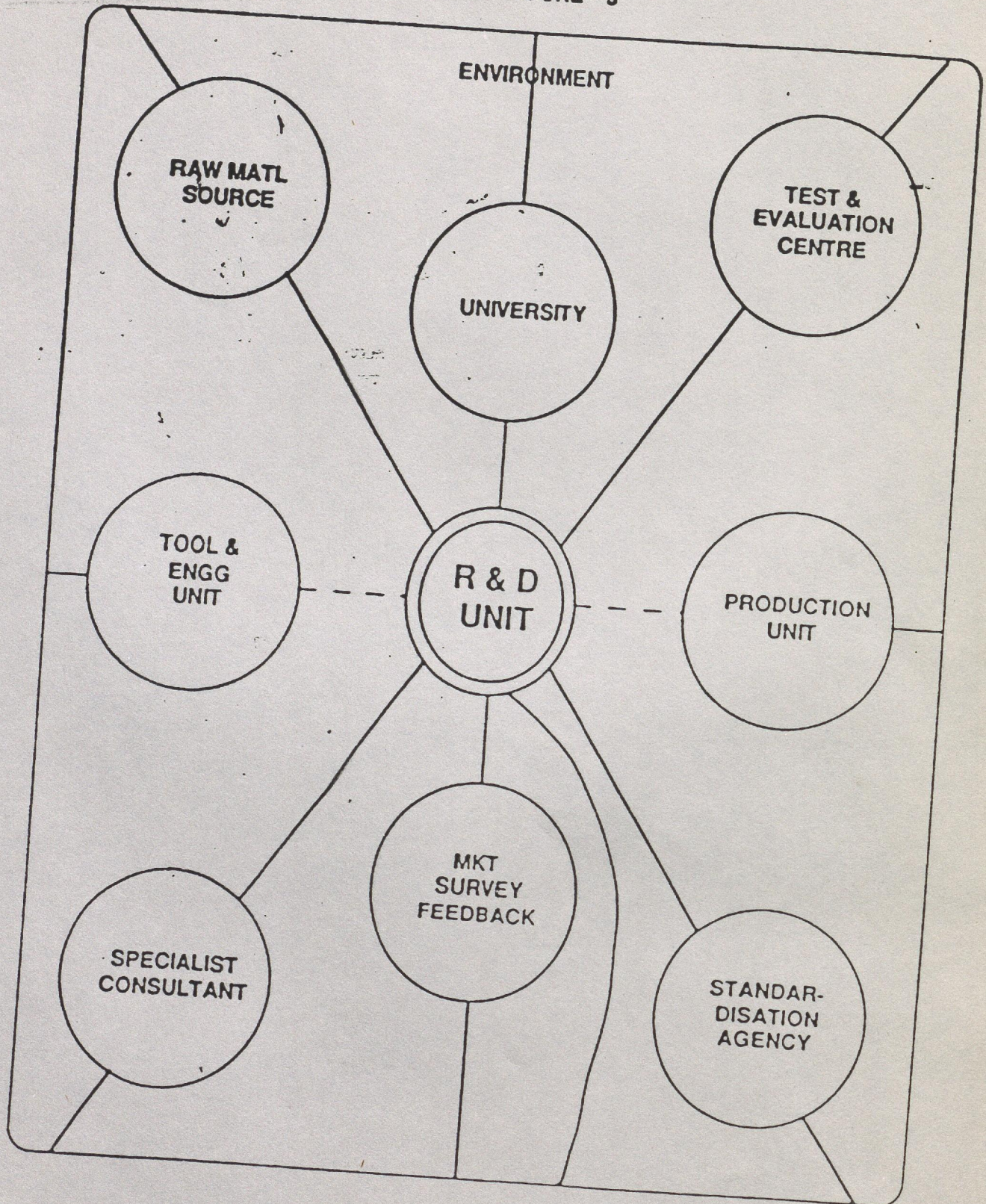
Research Through Development of Use

Phase	Description of Activity	Nature of activity
1	Scientific principle, invention or discovery of a new phenomenon	A Pure research without industrial motive
2	Preliminary measurement and analysis	
3	Basic research necessary to get an understanding of the phenomenon	B Applied research where scientific staff trained in A are required
4	Construction of first workable model with application in mind	
5	Development of prototype for demonstration	
6	Demonstration and evaluation to assess value for production	
7	Engineering Design of production models	C Development by engineers with production in mind
8	Tooling and manufacture	
9	Inspection, quality control, and testing	D Manufacture, marketing and use
10	Marketing and acceptance by the public buyer.	

This is the area where close attention by policy management first appears

improvements and modifications

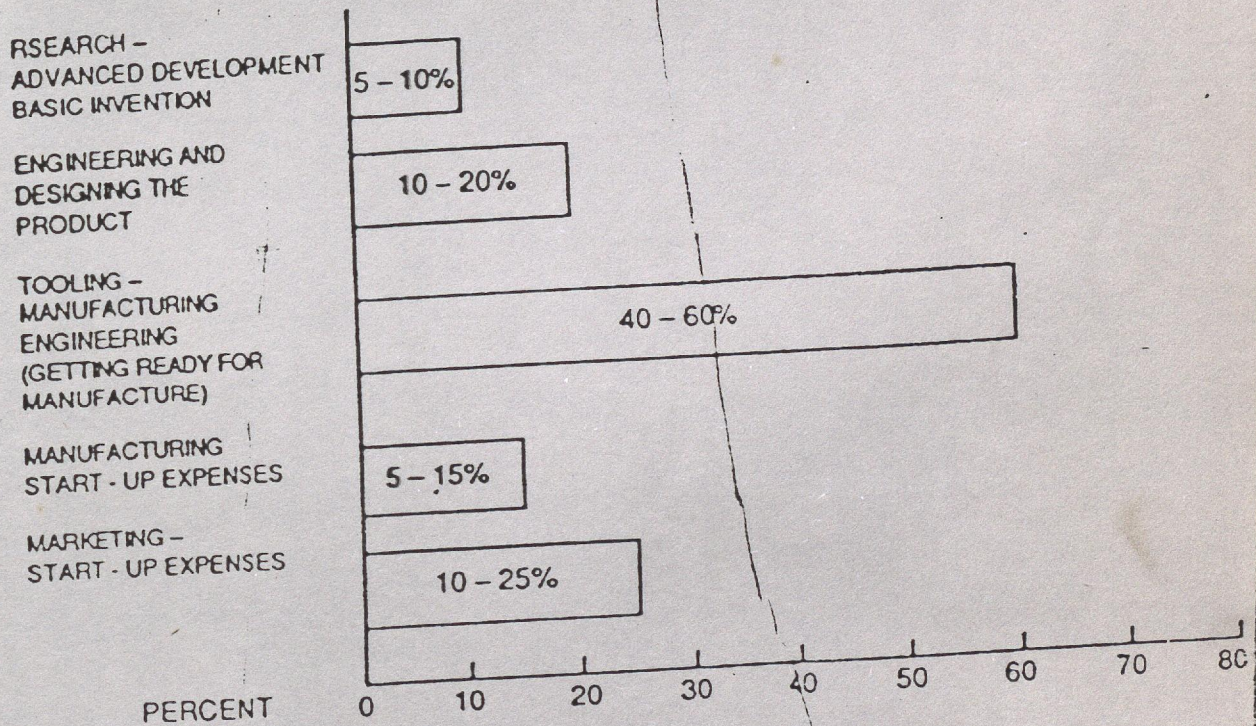
FIGURE - 3



LINKAGES NEEDED FOR R & D UNIT

FIGURE - 4

### TYPICAL DISTRIBUTION OF COSTS IN SUCCESSFUL PRODUCT INNOVATIONS



**ILLUSTRATIVE LIST OF PRODUCTS IN PRODUCTION**  
**BASED ON DOMESTICALLY DEVELOPED TECHNOLOGIES**  
**BY COMPANIES**

**ELECTRONICS****Computer and Computer-based Systems**

(a)	Computerized Railway Passenger Reservation Systems	Rs. 500 crores worth of such systems supplied to Railways by CMC
(b)	Computer-based Freight Operations Management System for Railways	Rs. 700 crores of system implemented on all 7 zones of Railways and the central control system at Delhi. Unique on a world scale & tailor made to meet needs of IR.
(c)	Computerized Automation of Felixtow Port in the UK	Rs. 200 crores worth of systems executed on turnkey basis by CMC under an order won against a global tender.
(d)	Computerized Automation for Bremerhaven port in Germany	Rs. 185 crores worth by CMC also against global tender.
(e)	Computerized Ticketing System on the London Underground	Rs. 70 crores by CMC also against global tender.
(f)	Computerized Automation of the Damascus Games, Syria	Rs. 55 crores by CMC also against global tender.
(g)	Supercomputers developed by C-DAC (Centre for the Development of Advanced Computing)	50 computers made over 1992-2002 at unit price of Rs. 45 lakhs to Rs. 1 crore depending on the configuration plus 15 systems exported mostly to Europe. Enquiries recently received from Singapore and South Korea. Of very high strategic value—denied by USA
(h)	SIMPUTER (Simple Computer) developed by IISc. Bangalore over 1998-2000 and licensed to two spin-off companies M/s. Pico Peta and M/s. Encore Software Ltd Unique graphic based system useable even by illiterates	Pilot production of 10,000 units each done by both companies over 2000-2002 at a unit price of Rs. 15,000/-. At production level of 100,000 nos / year price will be Rs. 900/- and at 200,000 level Rs. 600/-

(i)	Static & Mobile Computerized Data Handling System for the nation's Air Defense System	Rs. 500 crores worth supplied by ECIL over 1985-95 with features tailor made to meet IAF's specific operational needs
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ECIL : Public Sector Company Electronics Corporation of India Ltd.

### Telecommunications

(a)	Pulse Code Modulation Digital Multiplex equipment for BSNL and MTNL	Rs. 1000 crores by 6 public sector cos.
(b)	State-of-art Digital Electronic Telecom Switching Systems based on C-DOT technology	Rs. 10,000 crores supplied to BSNL & MTNL by 5 companies over 1996-97 to 2001-02 won against global tenders
©	Optical Fibre Communication Systems for the DOT, Railways Oil Pipelines and Defence Forces	Rs. 500 crores by public sector company OPTEL, Bhopal over 1990-92
(d)	Army Radio Engineering Network	Rs. 1500 crores over the 90's by BEL, PUNWIRE and PCL
(e)	Wireless in Local Loop (WLL) Telecom Systems developed by IIT, Chennai	4 companies—2 each in the public and private sectors—have been licensed the technology by IIT. All have received large orders from BSNL and MTNL. ECIL has secured a 0.5 million line order from Malaysian Telecom worth Rs. 200 crores in competition with the world's largest telecom company, Alcatel of France.

### Radio and TV Broadcasting

(a)	100 Kilowatt Mediumwave Radio Transmitters	Rs. 500 crores worth supplied by BEL over 1982-92
(b)	10 Kilowatt and 1 Kilowatt TV Transmitters	Rs. 750 crores worth supplied by BEL over 1983-1995
©	100 Watt Low Power TV Transmitter	Rs. 1200 crores worth supplied by BEL and GCEL over 1983-95
(d)	TV Receive-Only Terminals receiving TV broadcasts from INSAT for rebroadcast by the ground-based TV transmitters indicated above	Rs. 2000 crores worth supplied by BEL and ECIL over 1983-95

**We now have 1200 TV transmitters providing nation wide TV coverage through 6 INSAT satellites. This is the world's largest satellite linked TV transmission system in the world.**

BEL	:	Public Sector Company Bharat Electronics Ltd.
PUNWIRE	:	Public Sector Company Punjab Wireless Systems Ltd.
PCL	:	Public Sector Company Punjab Communications Ltd.
GCEL	:	Public Sector Company Gujarat Communications and Electronics Ltd.
OPTEL	:	Public Sector Company Optical Telecom Systems Ltd.

### RADARS

(a)	Airport Surveillance Radars	60 numbers produced HAL, Hyderabad at Rs. 5 crore a piece over 1992-2002
(b)	Air Route Surveillance Radar	40 numbers also produced by HAL, Hyderabad at Rs 8 crores a piece over 1995-2000
©	Precision Approach Radars (to guide aircraft while landing)	60 numbers produced by HAL, Hyderabad at Rs. 10 crores a piece over same period

### ELECTRONIC VOTING MACHINE (EVM)

(a)	Electronic Voting Machine (EVMs)	500,000 nos of EVMs each have been produced by BEL & ECIL at unit prices of around Rs. 12,000 over 1995-2000 involving a turnover of Rs. 1200 crores Unique product at the world level.
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HAL : Public Sector Company Hindustan Aeronautics Ltd.

## PHARMACEUTICALS AND FINE CHEMICALS

Our 8 top pharma companies—Ranbaxy, Reddy Laboratories, Cadilla, Torrent, Lupin, Sun Pharma and CIPLA—are producing Rs. 25000 crores of pharma products a year today—70% bulk drugs and 30% formulations. They are exporting Rs. 10,000 crores worth a year—80% bulk drugs and 20% formulations. Many of them e.g. Ranbaxy, Sun Pharma and Reddy Laboratories have set up plants abroad and also acquired companies in the USA. Reddy Laboratories has also set up an R&D Centre in the USA.

## Tractors and Agricultural Machinery

We have the world's largest tractor industry the bulk of which is based on domestically developed technology. The pioneer was Punjab Tractors which launched its tractor and tractor engine manufacturing lines as far back as 1975 and which has today a total turnover of around Rs. 2000 crores with a track record of high sustained profits over 25 years. It developed in the early 80's a totally indigenous Combine Harvester and is the only manufacturer in the country. That equipment has since been adapted for mine laying by the Army.

## Automobiles

The story of Indica and now Indigo are well known. Then there is the beautiful station wagon Scorpio developed by Mahindra and Mahindra which is giving a run for its money to Toyota's Qualis in every technical feature and also commercially. The development of Scorpio was started in mid 1998 and the first commercial sale was made in June, 2002 i.e. in a record time of four years. Mahindras spent a record sum of Rs. 200 crores on the design and development (D&D) of the Scorpio while the total investment

made on the complete manufacturing line was about an additional Rs. 600 crores. The total D&D plus manufacturing cost of around Rs. 1000 crores is 20% of what Toyota is known to have made on Qualis.~ Scorpio's five models are sold at an ex-works price of Rs. 6.57 lakhs compared to Rs. 5.97 lakhs in the case of Qualis. In 2002-03 our auto industry exported 5.5 lakhs vehicles led by the Indica and mostly to Europe.

### Solar Photo-Voltaic (PV) Systems

Over the decade of the 90's and into the present decade we have become a major manufacturer of solar PV i.e. solar electricity cells, modules and systems. We now have some 30 companies manufacturing SPV systems. The output of this hi-tech multi market industry has increased from Rs. 320 crores in 1995 to Rs. 750 crores in 2002. We are now the fifth / fourth largest SPV manufacturer in the world with our output constituting 15% of world output. Our companies have also exported SPV systems to some 15 other developing countries and the lead company, the public sector enterprise, Centrel Electronics Ltd (CEL) has even set up an SPV module and systems manufacturing plant in Syria.