

**RESEARCH AND DEVELOPMENT PROJECTS  
PROBLEMS OF COST - BENEFIT ANALYSIS**

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**INDUSTRIAL PROJECTS COURSE 1974**

**PROJECT PLANNING CENTRE**

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## RESEARCH AND DEVELOPMENT PROJECTS

### PROBLEMS OF COST-BENEFIT ANALYSIS

"Investment in research, as all enquiries is directed to change the future state of civilisation" - Bernal.

#### Introduction

The progress in the area of scientific Research and Development is astounding in the last half a century, particularly in the post second world war period. A new group of industries called 'science based' has grown sizably and such industries for example electronics, synthotic fibre etc. have become integral part of contemporary life. The economic demand for innovations has developed science itself. Investment in research is considered to be one of the major sources of growth of international product.

#### 1. Classification of Scientific Research

1.1 Scientific research is broadly classified into three categories viz. Basic, Applied and Development. The basic research may be treated as a part of educational system, since its main motive is the advancement of knowledge. The applied research and development are of great practical commercial/and industrial significance.

The percentage of expenditure for various areas of research by the manufacturing industries in U.K. in 1967 is shown below:-

Basic Research	.. ..	3%
Applied Research	.. ..	19%
Development	.. ..	78%

In U.S.A., the R & D expenditure was distributed in the following proportions (1961)

a) Product development	.. ..	45%
b) Product improvement	.. ..	41%
c) New process	.. ..	14%

1.2 In the R & D area, definitions of the following terms and concepts are of crucial importance.

a) Invention:

Invention is the creation of new technological knowledge which is normally patentable and it occurs subsequent to, or at least separate from research which can be defined as a process of adding to scientific knowledge.

b) Development:

It is a process of selecting the most promising research results and using them to create new processes and

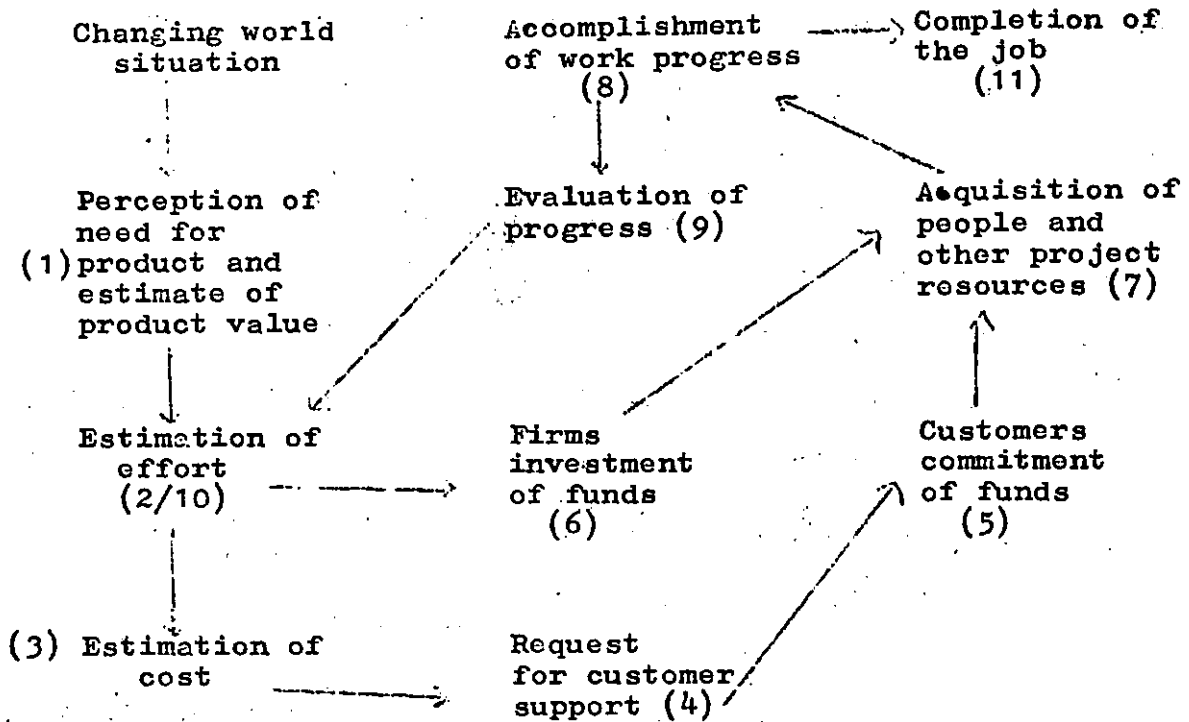
products. Commercial objectives and production possibilities predominate in this stage. An integral part of the development is designing of models and proto-types.

c) Innovation

Innovation is the utilisation of the knowledge obtained after invention and development for actual productive purposes. "In technical terms innovation operates either to create or alter demand functions or to lower cost functions(5)

Technical progress is defined as any change in National output that cannot be explained by increases in inputs. Technology is the systematic application of scientific or other organised knowledge to practical tasks.

1.3 The life cycle of R & D Project is described as the interaction between R & D products, the firm, the customer and the process relating to the nature of the work itself and the same is depicted in the diagram given in the next page.



(Source: The Management of R & D George T. Thomason Page 81)

1.4 The classification of new products and technologies into a chart form is given in the appendix.

## 2- Importance of R & D

2.1 The expenditure on R & D by the developed countries ranges between 2 to 3.6% of the gross National product at factor cost and 50% of such expenditure is accounted for economically motivated projects. It is observed that

"Science activity increases exponentially at a compound interest rate of roughly seven percent. At this rate science and science man power double in size every 10 to 15 years and have expanded by a factor of approximately one million in three hundred years since the publication of the first scientific paper. More than half of the overall growth in National and International product measured in constant money terms can be attributed to technological innovation" (2).

2.2 The spectacular creations of R & D in the form of Television, Jet travel etc. which were non existant before 1945 are estimated to have contributed more than 10 billion dollors to the Gross national product and created more than 2 million direct jobs and sizable indirect employment.

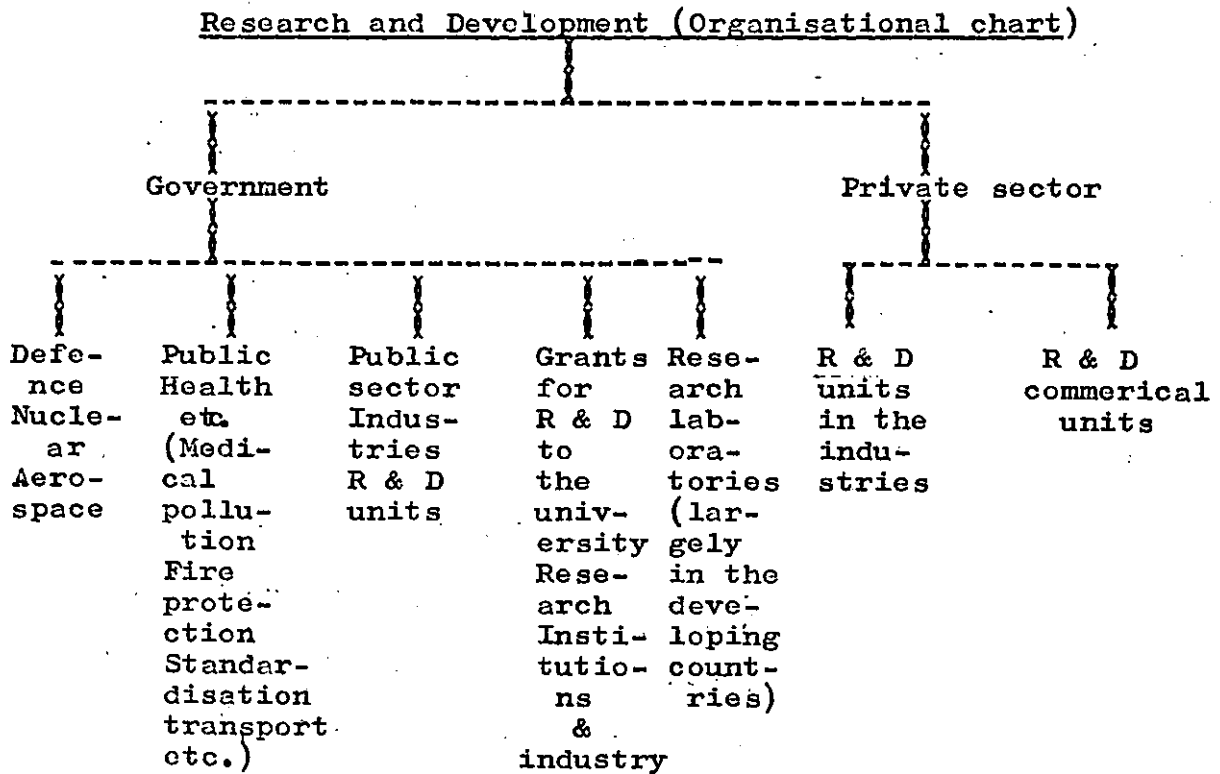
2.3 It is estimated that "The growth of production in the U.S.S.R. is attributable to the extent of 85-90% to growth of Labour productivity and this in turn is due to the extent of 70-75% to the technical progress. Thus at least 60-67% of the growth of industrial production is attributable to the new technology" (3).

2.4 Governments share in the expenditure of R & D ranges between 50-60% in the case of developed countries and more than 80% in the developing countries.



## 2.5 Institutional frame work of R & D activities

A chart detailing the broad institutional break-up of R & D activities is depicted in the below chart. The growing share of Government in the form of various activities is borne out by the chart.



## 3. Objectives of R & D projects

3.1 The R & D projects broadly aim at developing and introducing new or improved products and processes. Some

detailed objectives are stated below:

a) Maintaining the existing level of profits. (The new products introduced by innovation may affect the market of the existing product and hence constant improvement is necessary even to maintain the rate of profits).

b) Expansion of market by quality and service improvements.

c) Lowering the input costs leading to decreased sale price and consequent improved sales.

d) Quality improvement or functional addition leading to higher sales price or with the same price but additional sales.

e) Introduction of new products (If covered by patents such products enjoy lead period monopoly sales.)

f) The State sponsored research is mainly devoted to defence, production of nuclear power, public health, standardisation, fire protection, transport etc.

3.2 In the developed countries, it is said, that there are two conflicting explanation for the distribution of R & D efforts viz. "Technology push" and Demand pull. The former is based on the view that technology offers greatest

scope for advance and profit in a small group of science based industries. These industries are usually capital and consumer durable good industries whose customers are more likely to place value upon technical excellence and newness than the consumers of other products. These products combine to give a relatively high return to R & D expenditure" (1).

3.3 The following objectives receive increased emphasis in the developing countries.

a) Development of products and processes to facilitate the restructuring the export production from raw to intermediate and finished products to enhance the foreign exchange earnings. b) Import substitution in the industrial auxiliaries, chemicals, machines and tools. c) Introduction of suitable intermediate technology to enhance the earnings of underemployed rural and urban small units and household enterprises. d) to increase food production. e) to achieve substantial self sufficiency in the defence needs. f) Social amelioration of the depressed classes (both socially and economically) engaged in certain types of industries. For instance in the early part of the country, tanning industry had been looked down by the society as not a dignified pursuit. But after the initiation of the

Central Leather Research Institute, more than 200 qualified technologists (including more than a score of Ph.d holders) are serving the industry drawn from all the sectors and the communal isolation of the industry has been largely broken.

g) Man power benefits - skilled technologists are made available to the industry. h) Finally science has cultural benefits and the society may derive satisfaction from the National prestige that high quality scientific research may bring.

3.4 The detailed account of the importance, objectives and structure of R & D projects is intended to give a background idea about the complexity of the problem in the cost-benefit analysis. There are multiplicity of objectives at different levels and institutions and there are different degree of satisfactions of the same product according to the clientele and over a period due to inroads of new or substitute products.

#### 4. Problems of application of cost-benefit analysis in the R & D Projects

4.1 The difficulties of selecting, isolating and measuring relevant costs in the preparation of the projects are often expressed by the evaluators. The participation of

scientists and technologists in the R & D project is of crucial importance and evaluating their cost in the project is beset with problems.

4.2 Uncertainty in achieving the exact objectives is a major constraint in the preparation of R & D projects. The realised objectives may be more, different, near same or even nil. Invention is aimed at something new and hence cannot be carefully planned. The correlation between expected and actual returns in U.K., as per a study was found to be 0.13 with over and under estimation of the probable yields being equally likely. The greatest uncertainty will be in sectors where technological knowledge is changing rapidly. "On the basis of some evidence, it seems that about half of research and development projects yield no commercially applicable results. As such it is a heroic task for a firm to attempt an appraisal of R & D projects using numerical techniques"(1). It is further reported that "all available evidence points to a heavy mortality in research projects. For example the average experience of 20 companies in the Chemical Industry shows that only one successful product results from every eight projects that go into Research. Survey results covering more than 100 major companies show the median

failure rate to be about 67" (4)

4.3 Patents are supposedly to be taken after successful completion of innovations. The number of patent application and successful grants in U.K. are given below:-

<u>Year</u>	<u>No. of application</u>	<u>No. of grants</u>
1963	51468	30148
1967	59290	38999

(Source : 1)

Based on a two year lag between applications and grants, it can be seen that about 70% of patent applications are successful. This is to illustrate further the nature of uncertainty even in an advanced stage of R & D work. It is observed that the majority of the National patents in the less developed countries are owned by individual inventors, and such patents have minimum of industrial and business importance. For instance in Argentina 75% of the patents were owned by individuals and 75% of the patents did not result in successful industrial or commercial exploitation.

4.4 Another noteworthy element of uncertainty is the length of time which usually elapses between the initiation of research project and the release of the product for sale

in the market. From case studies, it is estimated that the time interval from the invention of new process product to its first sales on a commercial basis on an average is (with considerable variation between firms and industries) ten years. Thus the total interval between research and its application would often be more than fifteen years.

4.5 The yardsticks used in the assessment of benefits with policy goals are also varying. For example reduction in the mortality or disease may be the objective for Medical R & D while the increased destruction of human life may be the criterion for defence R & D.

4.6 Many welfare and amenity benefits flow from R & D work such as reduced loss of life, improved health, more leisure time called unsold time, prestige, entertainment etc. and these are difficult to be attributed any monetary value.

4.7 Research is an internal investment for the firms, like advertisement cost and does not reflect in the output accounting and hence studies on the effects of the R & D by the firms are difficult.

4.8 In the absence of indepth studies to get at some benchmark estimates for the various segments of R & D

activities, no dependable statistical base is available to apply the tools of cost-benefit analysis.

#### 4.9 Problems of measurement of research results in India

a) The R & D applied research institutions in India were mainly started by the Government to aid the industrialisation and not with any professed commercial objectives. In the growing nationalisation of the basic industries, some of the institutes concerned with fuel, metal etc. help the related nationalised industries in modernisation of production techniques besides serving as technical consultants. In the case of certain industries like leather most of the producers are small industrialists and hence the processes have been largely given free or at nominal cost through extension technicians. However the institutes have devoted considerable time in developing products and process for import substitution and export promotion. With the expertise available, the institutions offer technical consultancy to the industries and public sector institutions. There is an increased awareness to correlate the Input and outputs of research in India and to facilitate the building up suitable data base, projectwise budgetting and planning of research are being attempted. A macro level study of the contribution of research results of the institutions in monetary terms was



also attempted by calculating the actual monetary receipts, computed value of services offered and discounted potential benefits in the receipts side and the actual expenditure over the effective functional period of the institutions. This is of course a too broad based study to throw any definite guidelines for cost-benefit analysis of R & D research.

b) Regarding diffusion of research in developing countries it is observed "those large parts of the economy where the remnants of precapitalist organisations persist, for example subsistence agriculture and rural craft industries, generate very little demand for local scientific inputs. Consequently science in such countries is largely consumption item whereas in industrialised countries it is an investment item". The observation is not true for India and much relevant adaptive and new applied researches <sup>are</sup> /being undertaken to meet the demands of various sectors. The industrial utilisation of research is increasing rapidly in the last decade.

5. Measuring the R & D benefits - Some partial and indirect methods

Despite the problems of uncertainties looming large over the costing and expected returns of R & D projects, some

attempts have been made to measure largely the output of the R & D.

5.1 As referred to earlier, the fundamental research may be treated as a part of educational system. The funding of such research is not generally done with the micro-economic motive of costs and benefits. The output of such research can be measured rather notionally by the number of papers published, standard of the journals, the number of times cross references made and the extent of utilisation of the knowledge for further fundamental and applied research. Ascribing certain values for the above mentioned items are fraught with problems nor will it be easy to quantify the cost of the researcher. The research leader might have given only a bright idea and the entire work would have been done by his associates. The time spent in giving such idea and the related salary of the leader may not be right value for the idea, since he might have spent his active life time to get at the matured wisdom. Incidentally pay-offs from basic research may occur many years subsequent to the original expenditure.

5.2 The defence research has a broader National objective.

By convention the outputs of defence research are measured by costs resulting in zero contribution to measured productivity by definition.

5.3 The Government sponsored research with the end objectives of welfare like Public Health, fire protection etc. are not strictly amenable for measurement, though there is wide scope to stretch the benefits such as the number of human lives saved, diseases prevented and accidents avoided. Similarly the expenditure on researchers relating to aero-space, atomic energy etc. cannot be strictly related to the expected benefits. The expenditure on such items is more scientific than technological.

5.4 The applied industrial research which forms more than 60% of the total expenditure on R & D is the cardinal area requires cost-benefit analysis. Some of the measures suggested to measure the overall or partial benefits of R & D work enumerated below:-

5.4.1 The overall performance in scientific innovation of industrially advanced countries is measured by the following six indicators:-

- a) The location of 110 significant international innovations since world war II.
- b) Monetary receipts for patents, licenses and technological knowhow.
- c) The origin of technology imported by Japan.
- d) The number of patents taken out by each country in foreign countries.
- e) Export performance in research intensive industries.
- f) Export performance in research intensive product group.

The six indicators are applied in the following table to four major industrial countries:- (2)

	<u>U.S.A.</u>	<u>U.K.</u>	<u>Germany</u>	<u>France</u>
a) No. of inventions out of 110 significant inventions since World War II	74	18	14	2
b) Monetary receipts for patents and technological know-how 63-64 (in 8 million U.S. dollar)	348.7	76.1	49.4	46.3
c) The origin of technology imported by Japan (60-64) No.	1218	121	255	63
d) The number of patents taken in foreign countries 1963 (00)	56.3	15.2	29.9	9.3

	<u>U.S.A.</u>	<u>U.K.</u>	<u>Germany</u>	<u>France</u>
e) Export performance of research intensive industries 63-65 %	30	14.2	5.9	22
f) Export performance in research intensive product growth 63-65 %	31	13.9	5.7	21.1

The above details are only broad indicators of progress of R & D in the National level. The technological supremacy of U.S.A. followed by U.K. is evidenced by the data.

5.4.2 Certain areas of R & D are amenable for working out the costs and benefits. A detailed study was made on the cost effectiveness of mechanical potato harvester by Grossfield and he established the differential benefit between hand picking and mechanical harvesting in relation to investment for farmers with different extent of land. The R & D work as per the study was a financial success (if the expenses incurred for the previous attempts to develop a harvester were ignored)..

5.4.3 The effect of successful innovation on a firms growth rate is considered as a measure of R & D success. It is found that the average effect of a successful innovation on the steel and petroleum industries was to raise a

firm's annual growth by 4% to 13% (2).

5.4.4 Some economists have attempted to relate industrial R & D expenditures and innovations to world market performance. It is argued that at least for free market countries, the world's export market provides a fairly objective test of the innovative product's success of a firm or industry. (If a firm is introducing a new product in the world markets then it may enjoy a monopoly position in the sales till substitutes are developed abroad. This emphasises the importance of 'lead time' in the R & D activities) (2)

5.4.5 It is suggested that an input-output matrix relating to a country's industry to the R & D system could be constructed by a novel method of measuring research productivity. "This method would save the utility of various types of research for each industry and would also take into account the upstream and downstream of flows of information within the research system by a separate matrix for the transactions of R & D system. Its successful application would depend however not only on some measurement of these difficult intermediate and feed back flows but also a large number of peer judgements of every industry

about the research productivity relevant to that industry. Thus at the end the method comes back to dependence on the type of subjective evaluation of quality and importance of research output, which bedevils so many output measurement techniques" (2).

5.4.6 Another indirect method suggested is to classify the technological progress into a) productivity b) benefits of increased educational skill attainment c) improved health d) design and product innovations attributable to research e) economies of scale and f) of improvements with the organisation of markets such as the removal of restrictions in the mobility, economic effectiveness of resources and managerial efficiency. These forces are meant clearly to refer to the growth of output that is not accounted for by the contribution of labour inputs measured by a straight count of indifferential man hours of people employed and of capital services measured by the quantum of its inputs. The problem of measurement in this framework is the quantification of each of these forces, so that their sum represents total technological advance.

5.4.7 In the R & D project planning uncertainty shrouds the

future to a great extent. It can be obviated to a certain extent by using the existing knowledge of laws of science, experience obtained in respect of similar situations and of the past achievements. All these may be used to spell out the objectives for applied research which are believed to be attainable to a reasonable extent. Such objectives can be expressed in operational terms but will be ultimately subject to implicit or explicit economic constraints. These are however subjective estimates made by the experts in the field. Since the estimate is subjective it is advisable to increase the number of experts consulted to obtain a broad concensus of judgements (6).

5.4.8 The following has been suggested as a simple formula for ranking the research projects:-

$$\frac{pt \times pc \times (p - c) \times V \times L}{\text{-----}}$$

Total costs

- pt = Probability of Technical success
- pc = Probability of commercial success
- p = Price
- c = Cost
- V = Annual Sales volume
- L = Life of the project.



It is however felt that a better method would be to incorporate the expected total benefits and expected total cost. The formula appears simple but the problems of finding the exact parameters for each item is stupendous.

5.4.9 Another attempt was made to correlate the R & D expenditure and the GNP growth and the relevant data are reproduced below:

<u>Country</u>	<u>R &amp; D expenditure Percentage of G.N.P. at factor cost (1963)</u>	<u>Economically motivated R &amp; D as % of G.N.P.</u>	<u>Average annual growth of G.N.P. per head (60-68)</u>
Austria	0.3	0.2	3.8
Belgium	1.1	0.9	3.6
Canada	1.2	0.6	3.5
France	1.9	0.8	4.4
Germany	1.6	1.0	3.4
Japan	1.5	1.1	9.2
U.K.	2.6	1.3	2.3
U.S.A.	3.6	1.0	3.7

(Source-(1))

It may be seen from the figures that there is no observable relationship between R & D expenditure and the growth of G.N.P. and the essential reasons including

a) R & D is only one of the factors that contribute for the economic growth b) the R & D mix may vary from country to

country depending on the needs. Expenditure on Defence R & D which is considerable may not contribute much for the growth of G.N.P.

5.4.10 Patent statistics provide an indicator of output realised from the R & D resources:-

PATENT APPLICATION IN U.K. AND ANNUAL GROWTH  
(Calculated from 1950)

<u>Year</u>	<u>No. of application</u>	<u>Annual growth</u>
1950	31683	-
1955	37551	3.5
1960	44914	3.6
1965	55507	4.3
1970	62101	2.3

It is observed that 90% of the patents are in respect of manufacturing industry and over the entire period 1950-70, the rate of increase of patent application is akin to the rate of growth of manufacturing output at constant prices.

"This confirms to the suggestion that inventive activity reflects the overall level of economic activity although relationship is by no means a close one in individual years" (1).

6. Concluding observations and suggestions

A detailed description of the problem is no solution

but may help to comprehend the problem base for evolving a suitable methodology to measure the R & D inputs and outputs. The inevitability of R & D to maintain the present comfortable standards of living is amply recognised and increasing share of international product is being ascribed to applied research and development. Governments share in the R & D expenditure is more than 50% in most of the countries with the solitary exception of Japan. It may be argued that when R & D is doing fine with the overall social rate of return is expected to be higher than the conventional form of investment in industries, what is the need for cost-benefit analysis? A methodology of cost-benefit analysis for R & D is imperative on the following planks:

6.1 R & D activity is a growing area but with sizable concentration among big corporations that can risk huge amounts. For instance I.C.I. spent £ 40 million to develop Terelene and Dupont spent \$ 100 millions to develop a substitute for leather called 'Corfam'. The high concentration of R & D activity has created a sort of producers' sovereignty at the expense of consumers' sovereignty. In this connection it is remarked that "Animal spirits govern much innovatory investment. It is further

observed that "few things have been more interesting in the last decade than the revision of public attitudes towards technical innovation in the U.S. and other industrial countries. Until very recent times, it was in all countries a nearly absolute social good. The word invention was for all practical purposes synonymous with progress. The Scientist and Engineer the source of such innovation were prime social benefactors. The encouragement of technical innovation was the central function of the modern state. But these attitudes are still strong but they are no longer unchallenged" (2).

If some guidelines can be given with cost-benefit analysis data for various types of industries, more medium and small industries may turn to R & D and this will help to have more competitive producers in the market and they will help to diffuse the concentration of R & D. In the long run this will serve the interests of consumers.

6.2 If a separate group of R & D industries are growing in future attending to the development of new or improved products or processes a method of cost benefit analysis will help the financial institutions to appraise the projects with regard to the financial viability to facilitate extension

of credit facilities.

6.3 Government is a major contributor in the R & D expenditure particularly in the developing countries. In the private sector, R & D unit will be the first casualty if it is not paying. Strict commercial approach is not possible in the public sector since the institutions serve the needs of the various segments of the industry and also the public institutions. It is however imperative to have a watch over the expenditure emanating from the tax payers and broad guideline to work out the costs and benefit is necessary for such institutions.

6.4 A sort of methodology to quantify the benefits of R & D is necessary to encourage the researchers themselves. Most of them do not know their real contribution to the society. The knowledge of their real contribution will boost their morale and may lead to further inventive activities.

#### 6.5 Suggestions

6.5.1 It is necessary to conduct in-depth studies relating to the success and failure stories of R & D work for different group of industries such as chemicals, pharmaceuticals, Engineering etc. The studies relating to various levels

of attainment viz., star performance, super success, success, break even, failure and utter failure for a group of products are necessary to arrive at a reasonable broad frame of cost-benefit analysis of suitable weightage. R & D is not only a scientific activity but various areas such as economic analysis, costing, marketing, engineering etc. are involved. Hence the study teams should be drawn from multidisciplines to facilitate total thorough approach to the problem.

6.5.2 The generally non-quantifiables such welfare, entertainment, prestige, social amelioration etc. may be ascribed certain values (as a proportion of costs, multiple of costs or treating them as shadow benefits with certain values) by experts from relevant disciplines. Though it may appear to be little crude and arbitrary certain standard universal values can be evolved for such benefits and it would in the long run help to know the relative merits of various inventive activities.

6.5.3 The most elusive area in the R & D evaluation is the measurement of potential benefits including the spin-off effects. A detailed probe is called for in this sphere.

6.5.4 Application of certain social cost-benefit analysis principles

a) The investment in applied research particularly in newer areas is certainly **risky** (particularly for new and small investors) and hence a premium value can be ascribed to the investment.

b) The Researchers form the main movers of Research and they do not have much opportunity cost in the developing countries. (Alternative better employment may not be available). It is suggested that some premium value may be added to their cost based on their value in foreign countries (of course with certain deflators for the disparity in the cost of living).

6.5.5 Agency suitable for carrying out studies on Cost-benefit analysis of R & D.

Being a recognised technological institution, Bradford University can under-take detailed studies to evolve suitable methodology for the programming and evaluation of R & D projects. The Project Planning Centre of the University can prepare a plan for such studies. The research students may be encouraged to take up this subject for research degrees leading to M.Sc. and Ph.d.

At the first instance complete literature survey can be done to know the real gaps in the area and also to make use of the work done earlier in this field.

6.5.6 As this is a global problem, the international U.N. Agencies, various National Science Foundations, Research Councils (Council of Scientific and industrial Research, New Delhi, India), public sector research Institutions may be approached to make a concerted and coordinated approach. The experience of various organisations would be a useful base to prepare the survey frame. Studies in the various economic regions of the world will give better representative details to work out a comprehensive, dependable and acceptable methodology to measure the Inputs and Outputs of scientific Research and Development.

(N. LAKSHMINARAYANAN)



Classification of new products & technologies

Increasing technological newness

	Product Objectives	No technological change	Improved technology to utilise more fully the company's present scientific knowledge & production skills	New technology to acquire scientific knowledge & production skills new to the company
Increasing market newness	No market change	-	Reformulation to maintain optimum balance of cost, quality & availability in the formulas of present company products	Replacement to seek new and better ingredients or formulation for present company products in technology not now employed by the company.
	Strengthened market	Remerchandising to increase sales to consumers of types now served by the company	<u>Improved product</u> to improve present products for greater utility and merchandisability to consumers.	Product line extension - to broaden the line of products offered to present consumers through new technology.
	New market to increase the number and types of consumers served by the company.	New use to find new classes of consumers that can utilise present products.	<u>Market extension</u> To reach new classes of consumers by modifying present products.	Diversification-to add to the classes of consumers served by developing new technical knowled-

Source: S.C. Johnson & C. Jones "How to organise for new products" <sup>5e</sup>  
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