TECHNOLOGY TRANSFER: A SYSTEM ANALYSIS APPROACH TO THE STUDY OF ITS FEATURES

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The objective, components, organization, constraints, environment, adaptation, and development features of a technology transfer system are enumerated and discussed with illustrative examples from published papers. Three models -- Clark and Guba, Castasia, and Efercett Rogers -- of the technology diffusion process are presented. The factors influencing the diffusion of technology from one country to another, from one enterprise to another in one and the same country, and from one person to another within a group or an institution are mentioned. The psychological, educational, historical, political, economical, sociological and cultural characteristics of the giver and receiver of technological know-how and the differences in their scientific and technological development and information richness are important factors to be taken into account in designing a technology transfer system. The recommendations of Castasia regarding technology transfer and national policy on science and technology in Asian countries in the perspective of the overall national development of these countries are quoted.

1 SYSTEM ATTRIBUTES

Designing a system for technology transfer at the national level has to be considered as a component of the national planning for the development of science and technology. The latter itself will be a component of the hierarchy of plans for socio-economic development of the country. In a systems approach to the design of a technology transfer system, the following elements will have to be taken into account:

1 Objective of the technology transfer system;

2 Components or inputs of the system;

3 Organization of the components of the system. ;

4 Constraints on the system;

5 Environment in which the transfer of technology is to take place;

6 Adapting and fitting the system to the environment through the formulation of necessary policies and the development of necessary devices, institutions etc;

7 Development of the system to meet the likely future demands on it; and

8 Agency/policy to secure the continued operation of the system.

The elements 1, 2 and 3 define the system and its elements, 4 to 8 are concerned with the continued effective operation of the system in the space-time contexts of the future We shall consider some details of these elements in the succeeding sections.

2 FEATURES OF SYSTEM ATTRIBUTES

21 Objective

The overall objective of technology transfer is to facilitate the assessment of the suitability, value etc. of an invention in a particular environment and to fit the characteristics of the invention to the characteristics of the adopting environment.

22 Components and their Attributes

The components of the technology transfer system, taken in the wider perspective, include:

1 The system as a whole;
2 The inventor;
3 The invention/new knowledge/innovation;

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4 The media and mode of transfer of technology; and

5 The receptor/consumer/user of the technology.

A study of the relevant attributes of each of these components is helpful in a better understanding of the technology transfer process.

221 System as a Whole

The attributes of the system as a whole that may affect the technology transfer include the following:

1 Whether the situation involves one-to-one, or one-to-many, or many-to-one or many-to-many (that is, many-to-one-to-many, or many-to-one-to-one-to-many) communication.

2 Whether the technology transfer takes place from one country to another or from one organisation to another within a country, or from one person to another within an organisation.

3 Whether the technology transfer is in the vertical direction (that is, down the hierarchy or up the hierarchy) or in the horizontal direction (that is, between points of coordinate status).

Annotation. - Such considerations arise not merely within an organisation but even globally. For example, between an economically rich and an economically less developed country; or between an information-rich country and an information-poor country; or between a governing country and governed country; or among a group of economically more or less equally developed countries; or among politically equally powerful countries; or among less developed countries with more or less the same GNP level.

4 The total social, political, and economic environment at the time of transfer of technology.

5 The total social, political and economic environment of the past in which the giver and the recipient of know-how have been respectively placed, and the expected change in the economic, political and social environment as a result of the technology transfer.

6 The urgency of affecting the technology transfer.

7 The "noise" or "garbage" or "resistance" or "eagerness" or "infrastructure" already present in the system attempting to or being forced to adopt new technology.

222 Giver of Know-how

The attributes of the giver of know-how that may affect the technology transfer include the following:

1 The giver's objective and motivation in transferring the technology;

2 The giver's psychological, religious, educational, social, cultural and related background;

3 The giver's ability to transfer and communicate his experience in this area;

4 The giver's normal and situational or contextual relation with recipient of the know-how.

223 Recipient of Know-how

The attributes of the recipient of the transferred technology that may affect the transfer process include the following:

1 The recipient's objective, attitude, and motivation for asking for the know-how;

2 The difference in the religious, educational, economic, social, and cultural background between the giver and the recipient of know-how.

3 The intimacy of the contact between the giver and recipient;

4 The recipient's personal experience in similar technology transfer contexts;

5 The difference in the technology richness between the giver and the recipient.

224 Medium and Mode of Technology Transfer

The attributes of the medium and mode of technology transfer that may effect the transfer process include;

1 Whether the transfer is directly between the giver and recipient or whether an intermediary is involved;

2 If an intermediary is involved in the transfer, then whether it is an individual, an institution or a machine system;

3 If it is a human intermediary, then several of the attributes mentioned with respect to the giver and recipient of know-how (see Sec 223 and Sec 224) are applicable to the intermediary;

4 If it is a machine intermediary, then the characteristics of the particular machine used;

5 The ability of the giver and recipient to use effectively the intermediary -- whether human or machine -- to achieve their respective objectives;

6 Tools of the transfer process: Verbal, non-verbal, language (natural or code), record etc;

The sources and means of transfer of technological know-how are dealt with elsewhere.

3 ORGANISATION AND STAGES IN TECHNOLOGY TRANSFER

The following charts and diagrams show the different ways of viewing the information and technology transfer processes from the stage of creation of an idea to its incorporation in the commodity or service production stream.

31 CLARK AND GUBA MODEL

The following chart mentions the steps in the succession of links between research,

Chart of Idea-to-Adoption Continuum

		Objective	Criteria	Leads to
1 Research	..	To advance knowledge: New ideas	Validity: 1) Hypotheses tested; 2) Generalisability	Basic for invention
2 Development				
21 Invention	..	To innovate. provide new solution to an operating problem(s)	1 Appropriateness or suitability 2 Estimated viability 3 Relative contribution (impact)	Invention
22 Design	..	To engineer: Systematise and arrangement of the components of the solution. To prepare a design or innovation package for institutional use	1 Institutional feasibility 2 Generalisability 3 Performance 4 Spin off	Design package
3 Diffusion				
31 Dissemination	..	To inform: Create widespread awareness of the invention among practitioners and potential users	1 Intelligibility 2 Fidelity 3 Pervasiveness 4 Impact	Awareness about the invention

Continued

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32 Demonstration	To build conviction: Provide opportunity to examine and assess the qualities of the invention	1 Credibility 2 Convenience 3 Evidential assessment (Alternative professional consideration)	Building conviction about the invention
4 Adoption			
41 Trial ..	Technology transfer. Assess the suitability, value, etc., of the invention in a particular environment	1 Adaptability 2 Feasibility	Building familiarity with the invention Establishing contextual suitability of invention
42 Installation ..	To fit the characteristics of the invention to the characteristics of the adopting environment	1 Effectiveness 2 Efficiency	Adaptation of invention to a particular context
43 Institutionalisation ..	To incorporate invention as an integral component of the system	1 Servicing 2 Evaluation 3 Support	Integrating the invention into the ongoing program Sensing the new problems and needs
5 New cycle of Research, Development, Diffusion and Adoption			

innovation, and adoption of the know-how in a particular production system. This model is a modified version of the one developed by Clark and Guba to illustrate the transfer of education innovation;

32 CASTASIA MODEL

The Conference on the Application of Science and Technology to the Development of Asia (CASTASIA), held in New Delhi in August 1968, also considered, among other things, transfer of technology. In the schematic diagram (See Appendix) presented by the conference, two different views of the relation between science and technology are sought to be reconciled . One view is that science and technology grow separately though there may be mutually beneficial relations between them. The second view usually attributed to socilaist countries "assumes that the most fruitful approach is to combine various statistical indicators of the development of closely interrelated fields of knowledge in the complex of the 'science-technology-production' chain". The comparison of the rate of development of a particular field of knowledge in each of the three links of the chain helps to draw definite conclusions. There is a differential rate of growth in the three sections -- highest in the sciences, lowest in the production section, and intermediate in the technology sector. This apparently conflicts with the "mutually beneficial" view mentioned earlier.

33 Rogers's Model

In the model developed by Everett Rogers the transfer of information and the adoption of technology is considered as a diffusion process. The elements in the innovation diffusion process are: Innovation; communication of innovation; social system environment; time; and adoption. Using Roger's framework, a diffusion of innovation may be stated as: "The process of adoption or rejection, over time, of some specific idea or practice, by individuals, groups, or other target systems, connected to specific channels of communication which may be complementary to social structures, and to a given system of values and cultures". The elements are linked in a paradigm as shown in the diagram in the Appendix.

4 CONSTRAINTS ON RATE OF TECHNOLOGY TRANSFER

41 Rate of Diffusion

411 Time-lag from Invention to Innovation

Surveys indicate that the time lag between invention and innovation varies to a considerable extent from one context to another and depends on several factors. Some inventions mark a major departure from the existing technique while others mav be of a routine kind. Change of taste, attitude, technology and factor pricing may be involved in some cases before there can be a profitable utilisation of an invention. Table 1 presents data about the estimated time interval between some inventions and corresponding innovation.

Some of the findings of the study were:

1 Average time lag:

11 The average time-lag was about 11 years in the petroleum industry.

12 The average time-lag was about 14 years in other industries.

2 Field of Innovation:

21 Mechanical innovations required the shortest time intervals, with chemical and pharmaceutical innovations taking a longer time in that sequence.

22 Electronic innovations involved the longest time lag.

3 Innovator:

31 The interval was shorter if the inventor himself attempted to innovate than wh n he merely disclosed the new concept and left it to others to innovate.

412 Acceleration of Diffusion

Killingsworth, Lynn and others claim considerable acceleration of the rate of diffusion between the early part of this century and the inter-war period, with a slight acceleration

Table 1. Estimated Time-lag between Invention and Innovation

S N	Invention	Interval (years)
1	Cotton picker	53
2	Spinning jenny	5
3	Spinning machine (water frame)	6
4	Spinning mule	4
5	Power steering	6
6	Steam engine (Watt)	11
7	Steam engine (Newcomen)	6
8	Jet engine	14
9	Turbojet	10
10	Fluorescent lamp	79
11	Wireless telephone	8
12	Wireless telegraph	8
13	Triode vacuum tube	7
14	Radio (Oscillation)	8
15	Gyrocompass	56
16	Self-winding watch	6
17	Xerography	13
18	Ball point pen	6
19	Zipper	27
20	Safety razor	9
21	Long playing record	3
22	Magnetic recording	5
23	Shell moulding	3
24	Titanium reduction	7
25	Electrical precipitation	25
	Petroleum production	
26	Distillation of hydrocarbons with heat and pressure	24
27	Distillation of gas oil with heat and pressure	3
28	Continuous cracking (Hommes and Manley)	11
29	Continuous cracking (Dubbs)	13
30	Clean circulation	3
31	Tube and tank process	13
32	Cross process	5
33	Houdry catalytic cracking	9
34	Fluid catalytic pellet	13
35	Gas lift for catalyst cracking	13
36	Moving bed catalytic cracking	8
37	DDT	3
38	Streptomycin	5
39	Freon refrigerent	1
40	Hardening of fat	8
41	Plexiglass, lucite	3
42	Nylon	11
43	Terylene	12
44	Crease resistant fabric	14

after 1945. The reasons for the acceleration of diffusion are:

1 Development of a variety and improved channels of communication of information;

2 Development of more sophisticated methods for determining the time at which equipment should be replaced; and

3 Greater receptivity to newer ideas and techniques.

413 Reduced Timelag in Application of Discovery

The table 2 presents data about the time-lapse between formulation of a principle and its use for the development of a device, over the period 1700 to 1960.

414 Reduced Time-lag between Innovations in an Industry

Table 3 and 4 presents data about the time-lapse between successive innovations in the field of marine engineering and internal combustion engine.

415 Commercial Development

A survey of the products on sale by different manufacturing firms in USA in 1960, indicated that 10 percent of the sales were of products developed during the immediately preceding five years.

Lynn, in a study of twenty major innovations during the period 1885 to 1950, has estimated,

Table 2

Discovery-to-Device Time-lag

Sl. No.	Invention	Year of		
		Discovery of Principle	Development of device or use	Time-lag
1	Internal combustion engine	1710	1892	182
2	Photography	1727	1839	112
3	Aerial flight	1809	1903	94
4	Telephone	1823	1876	53
5	Radar	1889	1935	48
6	Gamma ray	1896	1939	43
7	Atomic power release	1932	1945	13
8	Transistor	1940	1948	8
9	Laser	1958	1960	2

Table 3

Innovations in Marine Engineering

Sl. No.	Invention	First Plan	Commercial Success	Time-lag
1	Geared turbine	1629	1911	282
2	Steam boat	1661	1808	147
3	Propeller	1746	1836	90
4	Iron ship	1777	1829	52
5	Fixed contra-propeller	1869	1910	46
6	Diesel engine	1882	1903	21
7	Rotorship	1923	1926	3

Table 4

Efficiency of Internal Combustion Engine

Improvement	Period	Time interval (years)
Savery-Newcomen to Watt	1710 to 1795	85
Watt to Cornish	1795 to 1845	50
Cornish to Triple Expansion	1485 to 1885	40
Triple Expansion to Parson's Turbine	1885 to 1920	35
Parson's Turbine to High Pressure Turbine	1920 to 1950	30

1 The incubation period -- that is, the average number of years elapsing from the time of the basic discovery or invention and the establishment of its technical feasibility to the beginning of its commercial development; and

2 The commercial development period - that is, the average number of years elapsing from the beginning of the commercial development of a product/process to its introduction as a commercial product/process.

Data from Lynn's study are presented in Table 5.

416 Inference from the Findings of Studies

1 The time-lapse between invention and the innovations based on it has been decreasing over time;

2 The time-lapse is much shorter for consumer products than for industrial products; and

3 The time-lapse is shorter for innovations developed using government funds than those using private funds.

Table 5

Average Rate of Development of Selected Technlogical Innovations

Sl. No.	Particulars	Average time intervals (years)		
		Incubation period	Commercial development	Total
1	Time period			
	11 Early twentieth century 1885-1919	30	7	37
	12 Post World War I (1920-44)	16	8	24
	13 Post World War II (1945-64)	9	5	14
2	Type of market application			
	21 Consumer	13	7	20
	22 Industrial	28	6	34
3	Source of Development			
	31 Private industry	24	7	31
	32 Federal government	12	7	19

42 Inter-country Diffusion

421 Factors Affecting Diffusion

The socio-economic structure of a country should facilitate the free and rapid diffusion of new technology. The rate of diffusion is an important factor. For instance, in process industries, it would determine the rate of increase of productivity in response to the new process. Several factors affect the diffusion rate. While several potential users may learn about a new technology, they may not all be able to predict accurately about its future impact on the industry. There may be need for a considerable investment in R and D for redesigning and adopting the process before it can be profitably assimilated into the production system. Reallocation of resources may be necessary. New skills and expertise may have to be acquired or developed. A major technological change may involve serious problems of personnel adjustment to new products. Differences in social structure and social practices of communities can affect the diffusion process in the target system.

The complicated feature of the diffusion process is evident from this definition. Mansfield selects four major factors which appear to govern the rate at which an innovation reaches an equilibrium level of use. These are:

1 The extent of economic advantage of the innovation over existing methods or products;

2 The extent of uncertainty associated with using the innovation when it first appears;

3 The extent of the commitment required to try out the innovation; and

4 The rate of reduction of the initial uncertainty regarding the performance of the innovations.

The availability of information on each of these factors can accelerate arriving at a decision about the adoption of a technology by a target system.

422 A Study of Inter-country Diffusion

Although several factors complicate the picture of diffusion of technology, it would be useful to take note of some features, such as time-lag between invention and innovation.

Ray has reported on the inter-country diffusion of the following new processes:

1 Basic oxygen process in steel making (Oxygen);

2 Continuous casting of steel (casting);

3 Special press in paper making (Press);

4 Numerical control of metal working machine tools (NC);

5 Shuttleless looms in the weaving cotton and man-made fibres (Loom);

6 Tunnel kiln in brick making (Kiln);

7 Steel plate marking and cutting in ship building (Steel marking);

8 Float Glass (Glass);

9 Automatic transfer lines in the manufacture of engines for passenger cars (Transfer line); and

10 Treatment of malt with gibberellic acid in malt brewing (Malting).

Information was gathered on:

1 The date of first application in a country;

2 The diffusion since the first application (in terms of the number of users, share of new equipment/process in the total productive output, and the proportion of the output produced by the new technique); and

3 The firm's views of the advantage and disadvantage of the new technique compared with the technique in use, and the factors favouring or hindering the introduction and spread of the new technique.

Ray's data regarding the time-lag of each of a few countries behind the pioneering country are presented in Table 6.

Ranked according to increasing mean time-lag, the countries fall in the following sequence: UK (2.3); Sweden (3.2); France (4.2); Austria (4.5); Germany (5.1); and Italy (6.2) Whether the differences in time lag between the countries are statistically significant is to be verified with more data.

43 Inter-Enterprise Diffusion of Technology

431 Engineering Industries

In another investigation in USA, the diffusion rate of twelve innovations from one enterprise to another in four industries have been studied. The innovations studied were:

Table 6

Time-lag Differential Between Selected Countries

Sl. No.	Process/ Technique	Year of introduction	Pioneer Country	N of years of lag after pioneer country					
				A	F	G	I	S	U
1	Oxygen	1952	Austria	0	4	5	12	4	8
2	Casting	1952	Austria	0	8	2	6	11	8
3	Press	1963	Sweden	3	2	2	2	0	1
4	NC	1955	UK	8	2	7	5	3	0
5	Loom	1953-4	France	7	0	1	6	3	4
6	Kiln	1948	Sweden	9	1	11	3	0	0
7	Steel marking	1950	Sweden	-	10	3	12	-	0+
8	Glass	1958	UK	-	8	8	7	-	0
9	Transfer line	1947	France-UK	-	0	7	3	8	0
10	Malting	1959	Sweden-UK	-	7	-	-	0	0
			Mean	4.5	4.2	5.1	6.2	3.2	2.3

A = Austria; F = France; G = Germany; I = Italy; S = Sweden; U = UK

+ The extreme value (1902) for UK is omitted.

1 Bituminous Coal Industry
   (a) Shuttle car
   (b) Trackless mobile loader
   (c) Continuous mining machine

2 Iron and Steel Industry
   (a) By-product coke oven
   (b) Continuous wide strip mill
   (c) Continuous annealing line for tin plate

3 Brewing Industry
   (a) Pallet loading machine
   (b) Tin container
   (c) High speed bottle filler

4 Railway
   (a) Diesel locomotive
   (b) Centralised traffic control
   (c) Car retarders

Some inferences from the study were:

1 Diffusion of a new technique is generally a slow process. From the date of the first successful commercial application, it took about twenty years or more for all the major firms in USA to install centralised traffic control, car retarders, by-product coke oven, and continuous annealing. The period was about ten years in the case of pallet-loading, tin container, and continuous mining machine;

2 The rate of initiation varied widely (0.9 to 15 years);

3 There was also a wide variation in the initiation rate of diffusion (average 9 years).

432 Differences Among Farmers

Mansfield points out differences among individual farmers in the rate of adoption of a new agricultural technique. The farmers were classified as

1 Innovators (first 2.5 per cent to adopt a new process);
2 Early adoptors (next 13.5 per cent);
3 Early majority (next 34.0 per cent);
4 Late majority (next 34.0 per cent);
and
5 Final adopters (last 16.0 per cent).

Among these adoptor categories, differences were found in regard to attitudes, values, social status, abilities, group membership, and farm business characteristics. The innovators were found to be more cosmopolitan, seek out new ideas, and information, venturesome, reach decisions quicker, better educated, and more affiliations and friends outside their group. They tended to have larger farms, more specialised enterprise, and greater farm ownership. The prevailing, culture of the community also influenced the diffusion of innovation.

44 Diffusion of Information within an Institution or Group

441 Source of Ideas for R and D

Ideas and proposals for research, development and innovation arise from different points within a firm. For instance,

1 Innovations by competitors stimulate new projects;
2 New developments in science and technology may suggest new lines of research and innovation;
3 The sales and production divisions may make suggestions for new lines of work;
4 Customers often point out defects and ask for an improvement in a firm's product; and
5 Any individual or department in a firm is a potential source of new ideas.

In a study of over 100 industries, it was observed that

1 Sixty per cent of the topics originated from the R and D department;
2 Seventeen per cent from the sales department;
3 Nine per cent from the management; and
4 Four per cent from the customers.

R and D department was the more important source of ideas in the chemical, pharmaceutical and food areas, the sales department was particularly an important source in the metallurgical industry, and the Government was the important source in the electronics and aerospace industries.

442 Dissemination Media

The media for dissemination of knowledge that may result in a major invention or improvement of an existing technology are many and varied. These include

1 Document (External)
Book, periodical, technical report, patent, standard, specification, thesis, trade publications, review and trend report, preprint/reprint exchange, card services, indexing and abstracting services, etc.

2 Information dissemination centre.
Documentation centres, information analysis centres, clipping services, associations, etc.

3 Vendor/Supplier/Contractor
Representative of or document generated by, vendor/supplier/contractor.

4 Customer
Representative of or document generated by, the agency for which a project is carried out

5 Consultant/Adviser/Guide
6 Meeting
7 Mass media
8 Formal course
9 Through colleagues
10 Institutional source

Other institutional research projects; colleagues in the institution, documents generated within the institution.

11 Personal experience in similar, related, or other work.

Example

William J Price mentions the pattern of link between the scientific community and the research activity of the US Air Force Office of Scientific Research (=AFOSR). It is a two-directional communication -- information for finding solution to the scientific problems of the Air Force and the availability of information to the users. The link or coupling is established in the following ways:

1 Part of what the AFOSR purchases through contracts and grants is primarily designed to provide communication. The symposia and related sponsored research helps the AFOSR to keep abreast of the developments in science and technology; and

2 Direct involvement and participation of scientists through AFOSR contracts. For instance,
21 Trips to Air Force installations to provide consultancy service;
22 Membership on ad-hoc groups to study the feasibility of various exploratory-development programmes;
23 State-of-art review, either oral or written;

24 Special purpose symposia specifically designed to bring technologists and scientists together;

25 Special lecture tours;

26 Feasibility studies on research phenomenon to package them in a form more likely to be useful; and

27 Direct consultation with aerospace industries.

443 Differential Use of Media

The differential utilisation and performance of the different media of information in R and D activity have been studied by Allen and others. The process of diffusion of technological information and the several sociological, institutional and human factors affecting it within a scientific and technological community have been examined. The MIT Conference on the Human Factor in the Transfer of Technology, the University of Nottingham Symposium on Accelerating Innovation, and the report of Gilmore and associates are examples of such studies. There have also been a large number of "user studies" over the past three decades.

444 Documents as Source for Ideas

In a survey of 1082 technologists in UK, it was found that only 12 per cent used documents at the start of work, and once the investigation was underway, if they had not already consulted the documents it was unlikely that they ever would. Of the population studied, 60 per cent reported documents as major source for ideas or major stimulus for ideas. Impersonal channels of communication appeared to be preferred at the "interest" stage. These findings are similar to those of Allen, Gerstenfeld, and Gerstberger in a study of engineers in the R and D departments of biological and aerospace industries.

Allen has pointed out the effect of such use of information on the success of firm in landing government contracts.

445 Group Relationship

The structure of formal and informal relationships among the groups in the laboratories appear to have an effect on the information flow pattern. Allen and Cohen using sociometric methods, have compared in two laboratories the choice of communication methods — such as, technical discussion, critical incident information, and research ideas -- with the research worker's choice of social contact. In the case of one laboratory there was considerable overlap between the socialisation network and communication of ideas generated by research. In another laboratory there was overlap between social contact and both technical discussion and research ideas. In the second laboratory, it was also noted that the Ph Ds communicated little with non-Ph Ds; on the other hand, the non Ph Ds preferred to socialise and communicate with Ph Ds. The organisational structure of the institution is shown to have considerable influence on the communication patterns of R and D groups.

446 Information from within and from outside a Firm

Myers report based on a study of 560 decisions in railway, housing, and computer industries, indicates that 50 per cent of the decisions were based largely on technical information transferred by one using-firm to another; and about 50 per cent by information generated within the using-firm. The single most important media for such transfer of information was the vendor or potential supplier (15 per cent); and the Government was ranked next (10 per cent). The Governmental information was used differentially from the vendor information.

Gilmore's survey of industrial organisations indicates that the "Personal Channel" -- supplier, customer, consultancy, and meetings -- is the most widely used as external channel of information for problem solving.

447 Source of Information to Farmer

Among farmers, the prevailing culture of their communities was found to influence the rate of diffusion of information and the differential use of communication channels. The use varied in relation to the stage in the adoption process that the farmer had reached and in relations to the farmers' adoptor category. For instance, mass media sources were important at the awareness and interest stages; neighbours and friends were important at the evaluation and trial stages. The early users of a new technique tend to rely on sources of information beyond the experience of their peer group; and after they have successfully used the modern technique, they become the model for the less expert group.

448 Technological Gate Keeper

Studies on information flow in an organisation also indicate that some individuals act as "Technological Gate Keepers". A larger proportion of the technical personnel in the organisation turn to them for information and were the preferred choice in technical discussion. Such a person tended to be exposed to a great extent to documents and personal contacts outside the organisation. They received most of the information from outside the organisation and helped to desseminate it among the personnel within the organisation.

5 ENVIRONMENTAL FACTORS

51 Total Picture

In order to get a proper perspective of the long chain of events, it is necessary to examine it against the back-ground of the total socio-economic system. For, in a dynamic system with interacting components, a change in the value of any one of the attributes of any one of the components can produce change in the values of the attributes of the other components and even in the system as a whole. Research, Industry, and Documentation systems are components of the socio-economic system. Research produces ideas that can lead to socio-economic change. The enterpreneur uses the ideas to bring about technological change and produce the goods and services the society needs. The Documentation systems help to disseminate ideas, ostensibly to accelerate the technological change by establishing and stimulating communication between research and industry. The close interrelation between invention, innovation and economy is well summarised by Myers, Director of the National Planning Association, R and D Utilisation project. On the basis of a study of five hundred innovation he concluded. "Perhaps the best way to stimulate an innovation is to stimulate the economy as a whole... About one half of the innovations came about in direct response to market factors. A rapidly growing economy obviously expands the market for innovations and encourages business investment in new idea".

52 Pure Research and Technology

Studies have disclosed differences in the modes and media of diffusion of knowledge generated from pure research and that generated by technology. The following are some of the findings;

1 New information becomes known to a scientist's peers in the world scientific community much earlier than to other groups, well in advance of any formal written publication;

2 In technology, including the application of science and engineering, creative efforts are primarily concerned with the integration of previously existing knowledge to produce usable commodities and services including, for example, systems, devices, processes, methods and materials;

3 Pure research and phenomenon-oriented research are concerned mainly with the generation of knowledge of some phenomenon or other;

4 The knowledge generated from pure research and phenomenon-oriented research is made available to scientists and technologists in several ways and through several channels;

5 Technological events are usually initiated within technology, in the presence of ambient science. With a few exceptions, it is usually difficult to establish an unique correlation between an important technological advance with a piece of knowledge generated by pure research or phenomenon-oriented research; and

6 In general, technology feeds upon knowledge generated in the technological field, while pure research and phenomenon-oriented research feed upon knowledge generated in the field of pure research and phenomenon-oriented research. However, there are several interconnections across the two spheres of activity.

53 Key Factor of Economic Growth

531 Factors of Growth

It is now generally recognised that a good proportion of the socio-economic growth of a country depends on

1 Heavy investment in
  11 education
  12 research and development
  13 production and distribution of tech-

nical know-how,

14 improved information dissemination and technology transfer facilities

15 better organisation and management of research and industry; and

2 Use of improved materials, processes and equipment.

In other words, a good proportion of the investment is apportioned for the production and distribution of knowledge. Recently, Peter Drucker, the management specialist, pointed out that the United States of America spent on the production and distribution of information

25 per cent of the GNP in 1955;
33 per cent of the GNP in 1965; and
50 per cent of the GNP in 1970.

532 Key-Factor

Studies indicate that technological change is a key factor -- if not the key-factor -- contributing to economic growth. A technological change is an advance in knowledge as differentiated from a change in technique which is an alteration of the character of an equipment, product, or organisation.

54 Economic Growth and Technological Change

The need for maintaining a high rate of economic growth is a widely accepted concept. Countries with diverse socio-political systems and widely differing levels of economic development-- for example, USA, UK, France, USSR, Yugoslavia, India and Japan -- have set up targets for the rate of growth. Rough estimates have also been made of the impact of a country's rate of technological change on its rate of economic growth. For example, in USA,

1 Ninety per cent of the long term increase in output per capita resulted from technological change, increase in educational levels, and other factors not directly associated with the increase in labour and capital;and

2 Forty per cent of the total increase in income per person employed during the period 1929-57 was derived from advances in knowledge.

55 Technological Change and R and D Expenditure

A study was made of the Chemical, Petroleum and Steel Industries, using data regarding the number of significant inventions carried out by ten large firms in a few countries. Holding size of firm constant, the number of significant inventions has been found to be highly correlated, at least in the long run, with the amount spent on R and D. In the chemicals field, a proportional increase in the incentive output has also been observed. Studies further indicate that the rates of technological change appear to be related to the rate of growth of cumulated R and D expenditure of a country. Therefore, in most countries, an increasingly larger proportion of GNP is being allocated to R and D and to the acquisition of knowledge generated by R and D elsewhere. A point to be noted is that "... the relationship between R and D expenditure and national economics is complex, and several countries have spent a great deal of money on R and D in recent years without achieving any spectacular economic growth".

56 Research and Innovation

561 Research as Starting Point

Research is the source of new ideas which in turn, can produce technological change. Therefore, one of the main functions of R and D facility to industry is to solve problems and to generate new ideas for use in industry. For instance, a survey of business plans for new plant and equipment, carried out about a decade ago, provided the following information.

Table 7: Objective of R and D

SN	Objective of R and D	% of reporting
1	Develop new products	47
2	Improve existing products	40
3	Develop new process	13

The role of R and D for development of new products was particularly emphasised in the industries dealing with electrical equipment, chemicals, and fabricated metal, while the improvement of existing products was emphasized in those dealing with rubber and petroleum.

562 Research and Innovation

The table in Sec 31 indicates that new knowledge generated through research by itself may not directly contribute to technological change and economic growth. It is only when the idea or invention is assimilated fairly widely into the production system of a country that technological change and economic growth can result.

563 Innovation

One of the key factors of technological change is innovation. Innovation is the totality of scientific and technological effort culminating into a product or service. In market economy terms innovation is defined as the commercial exploitation of technical knowledge in order to

1 Win new markets, or
2 Hold existing markets against competition, by
1 Reducing the cost of production of existing goods, or
2 Introducing more efficient goods and services than the existing ones, or
3 Introducing new goods and services.

In the terminology of planned economy innovation involves the intentional introduction of ideas of science and technology into the production system in order to

1 Improve labour conditions; and
2 Speed up the general rate of economic growth adequate to meeting the growing demands of society.

564 Part of Innovation Process

Research and development constitute only a part of the total innovation process. In fact, economically speaking R and D expenditure is an overhead expenditure until the results are commercially exploited. Table 8 presents a general picture of the distribution of cost in successful innovation.

Table 8. Distribution of Cost

SN	Stage	% of total cost
1	R and D, basic invention	5-10
2	Engineering and design	10-20
3	Manufacturing engineering	40-50
4	Manufacturing start up	5-15
5	Marketing start up	10-15

It is obvious then that the benefits of technological change can be generally achieved only at the cost of heavy investments in education, in R and D, capital equipment, and marketing.

565 Enriching the Innovation Potential

In actual practice, innovation may arise not only from R and D, but from operational improvements introduced by a "productivity conscious staff and management personnel". A large number of minor improvements may be more important than a small number of breakthroughs.

Enriching the innovation potential requires:

1 Developing an environment helpful in promoting innovation in the whole chain of industrial activity-- research, development, production, marketing, and post-sales service, feed-back, and repetition of the cycle;

2 Selecting the appropriate advanced technology;

3 Applying the advanced technology before it becomes obsolete;

4 Bearing in mind that there may be competitors using similar or even more advanced technology; and

5 Developing a management structure conducive to maximising the chances of making gainful decisions in planning, organising, and controlling at all levels.

A successful innovation will have a significant impact on the rate of growth of the innovating firm. The impact is greater for a small firm than for a large one.

57 Buying and Borrowing Technology from Abroad

In the early stages of its development a country might find it more economical and helpful to borrow technical know-how from what ever sources available, including foreign countries. A good part of the local effort will be concentrated on innovation to adapt the imported technology to local conditions, available resources, social institutions and expertise. As development proceeds dependence on borrowed technology will be progressively reduced by investing an increasing percentage of the GNP on indigenous R and D. At all stages imported technology and local research effort should be effectively blended so as to be complementary to rather than competing with, each other. In this view it would be considered wasteful to use the limited resources in duplicating effort and reinventing know-how that can be more economically had from published documents, through licensing, etc. Reliance on the products of one's own R and D effort alone is neither necessary nor normally practicable.

571 Technical Know-how: Marketable Commodity

Every country has an interest in the dissemination of technical know-how. Arrangements for this purpose are becoming the subject of discussion at the national and international levels. It is beneficial to the donor as well as to the recipient. In fact technical know-how is now a standard commodity in the international market. The results of research are available internationally through published documents, private communication between specialists, and through conferences, seminars and similar meetings of specialists. Technical know-how may be disseminated through several channels -- such as, movement of people, technical cooperation programmes, joint ventures, licenses, patent agreements, foreign investments and the purchase of capital equipment and machinery.

572 Technological Balance of Payment

The international exchange of know-how can be shown by a technological balance of payments. Therein we may compare a country's payments to other countries for technical know-how, licence, and patents received with its receipts for "selling" such items. Table 9 presents some data for 1964 on such transactions. The data excludes the transactions between socialist countries and between those countries and developing countries.

573 Import of Technology by India

The findings of a recent study by the National Council of Applied Economic Research, New Delhi, are summarised below:

The data on payments made by India on technology imported from abroad are very fragmentary. The three countries USA, UK and West Germany probably accounted for 90 per cent of the royalties received in the international transaction of technology, and 90 per cent of India's technological payments went to them. India's share in international payments of royalties to these countries was marginally below 1.2 per cent.

It is estimated that the US receipts of royalties increased at about 15 per cent per annum in 1958-62; and that of India increased at about 11.5 per cent per annum from 1960-1 to 1968-9. If we assume the US rate of growth to apply to world royalty receipts in the same period, India's share would fall to 0.9 per cent by the end of the period. The ratio of India's imports to world exports fell from 2.6 per cent in 1960 to 1.3 per cent in 1967. India is a minor buyer of declining importance in the world markets for goods as well as technology.

Table 9

Technological Balance of Payment (1964)

Country	% of world total		
	Receipt	Payment	Balance
USA	57	12	+45
UK	12	11	+ 1
Germany (FR)	6	14	- 8
France	5	11	- 6
Other countries of W Europe	18	25	- 7
Japan	1	13	-12
Other developed countries	1	6	- 5
Developing countries	1	8	- 7

Table 10
India's Payment for Technology Import

Particulars	U S A	U K	West Germany
Receipts for technology (in million Rs.)	5700 (1962)	900 (1962)	375 (1963)
India's payments for technology (in million Rs.)	34.8 (1962-3)	37.5 (1962-3)	11.3 (1963-4)

The earlier foreign investment in India went largely to sectors relatively stagnant technologically; the picture has changed considerably since independence. Out of 423 agreements of companies with foreign equity participation, 419 had technical collaboration also. Dividends paid by the latter would compensate for import of technology as well as capital. Royalties have been growing much faster than dividends. It is thus probable that imports of technology have been increasing faster than imports of capital.

The survey covering the period 1951-67 indicates that some of the widely held views on import of technology are not tenable. The views found fallacious are:

1 Technology has been imported mainly by large firms;

2 Collaboration agreements restrict exports significantly;

Table 11

Dividend and Royalty Payments by India

Kinds of collaboration	Dividend (million Rs.)		Royalty and Technical Fees (million Rs.)	
	1960-1	1966-7	1960-1	1966-7
Subsidiaries	100	160	25	45
Companies with foreign minority holding	10	50	20	45
Purely technical collaboration	-	-	12	45

3 Collaborations are invariably harmful to indigenous research and development; and

4 Government control of royalties effectively reduces cost of technology;

The study also brings out the close relation between post-war imports of technology and capital; underscores the importance of research and development in reducing imports of technology as well as of bringing down its supply price; and emphasises that if research and development is to serve this purpose, results must be comparable to the world's advanced technology.

574 Assimilation of Technology is costly

It may be seen that even developed countries borrow technology from abroad. But to be able to utilise it profitably and generate newer technology for "sale" in the international market, it needs a suitable R and D facility to adapt, innovate and absorb the knowledge into the system. This again can be expensive. For sophisticated technology is often made available in the form of costly equipment and specialist personnel. Basic knowledge about the technology may be acquired through training abroad, published documents, technical information centres, licensing agreements, etc, but technology transfer does not easily take place in this way. In addition to developing the necessary skills and abilities for using the technology, there needs to be good management, organisation of production and marketing facility. A constant stream of innovation has to be stimulated and maximum productivity should be aimed at. The structure of economy,

Table 12

Firms' Sales and Forms of Imported Technology

Form of Technology	Firms' sales (million Rs.)					Total
	< 5	< 10	< 50	< 100	> 100	
Major imports of technology	281	333	825	388	361	2,188
Production knowhow	249	303	725	339	298	1,914
Plant construction	32	30	100	49	63	274
Preinvestment service	-	9	57	18	26	110
Problem solving	14	13	43	26	35	131
Indian personnel sent abroad	-	-	-	-	2	2
Foreign personnel sent to India	4	-	3	5	3	15
Drawings and specifications	11	17	63	26	28	145
Patents	16	4	82	39	40	181
All imports of technology	326	376	1,073	502	495	2,772
Other proposals	9	-	6	-	5	20
Total	335	376	1,079	502	500	2,792

Table 13

Forms of Technology Imported by Manufacturing Industires

Form of Technology Imported	in Million Rs.
Major Imports of Technology	2,270
Production knowhow	2,036
Plant construction	234
Preinvestment service	66
Problem solving	69
Indian personnel sent abroad	2
Foreign personnel sent to India	10
Drawings and specifications	125
Patents	129
All imports of technology	2,671
Other	12
Total	2,683

availability of local expertise in adequate measure, and the pattern of organisation and management of R and D and of industry and the distribution of scientists and technologists in research and industry affect the productive utilisation of ideas. In general, the wider the disparity in economic and technical levels between the cooperating countries, the less successful the transfer and adoption of technology is likely to be.

58 Socio-Political Factors

Several socio-political factors affect the transfer of information and of technology itself. Some factors are mentioned here.

Control or manipulation of content of information available for transfer or actually transferred including:

1 Censorship (political, ethical, religious); and

2 Selection of technology for transfer (that is , conditioning).

Schism that develops between those able and those unable to accomplish information and technology transfer . These can result from several cuases such as

1 Lack of education and training to interpret the information and technology transferred;
2 Lack of education and training to establish the transfer path;
3 Monopoly or oligopoly control of technological information;
4 Class and group structure differences;
5 Cultural differences;
6 Cost of access to technology;
7 Cost of using the technology;
8 Lack of common language;
9 Difference in background experience.

581 Misunderstanding and Misinterpretation

The experience of several UN missions to different areas of the world to introduce new ideas, innovations, and technologies, confirm the impact of socio-cultural and political factors on the success or otherwise of the mission. A good proportion of the failures is due to misunderstanding and misinterpretation of the socio-cultural systems of the adopting country. The technological achievements since World War II have been so dramatic that we have been able to share the hope that the people of the world need no more go hungry, ill-clad, or unsheltered due to lack of knowledge -- that is, inaccessibility to knowledge and/or the means of its utilisation. Yet we see vast numbers of people are living close to misery, fear, tension, and conflict. In many a case, even where programmes for the sharing of the affluence and misery between the haves and have-nots have been tried, the result has not been very encouraging. In some cases, it has been disastrous. Misunderstanding born out of ignorance has been the principal cause of such a state of affairs. We have been warned "how destructive contact has been in the past between technologically developed and technologically less developed cultures, how often the price of progress has been to turn proud aristocratic nomads into pitifully limited factory workers, shorn of their own tradition and provided with no new values. What is the cost of technological change" in terms of the human spirit? How much destruction of old values, disintegration of personality, alienation of parents from children, of husbands from wives, of students from teachers, of neighbour from neighbour, of the spirit of man from the faith and style of his traditional culture must there be? How slow must we go? Margaret Mead points out that these are some of the sociological questions to be considered in any attempt at information and technology transfer.

6 ADAPTING THE SYSTEM AND PROVISION TO MEET NEEDS

61 Trend

With a view to keeping pace with the growing demands of society, the developing countries in particular are placing emphasis, among other things, on the following factors:

1 Producing a variety of commodities and services in increasingly larger quantities;

2 Developing the know-how -- through its own R and D effort and on the basis of R and D work done elsewhere -- to convert the unconsumable natural and near-natural raw materials into consumable commodities;

3 Maximum practical utilisation of new ideas generated by research and innovation anywhere;

4 Securing maximum productivity in research, in the application of the findings of research, and in the production of commodities and services; and

5 Promoting a research and industrial climate conducive to new discoveries, inventions and innovations.

62 Protracted Process of Assimilation

The mere production and accumulation of a large volume of know-how does not ensure its proper and full utilisation by industry. Being aware of the existence and the availability of know-how also does not ensure its proper and full utilization. After research has created a piece of knowledge, there is usually a long incubation period before that knowledge gets assimilated in the stream of commodities and services. There is a long chain of events that usually links the idea generated by research with the commodity or services to which the idea may lead.

63 CASTASIA Recommendations

It will be appropriate to recall here the relevant recommendations of Castasia regarding technology transfer and national policy on science and technology in Asian countries in the perspective of overall national development.

631 Indigenous Research vs Imported Know-how

1 A country aspiring for rapid economic growth through industrialisation should

11 Ensure free flow of imported technology

12 Spend on this account an amount at least equal to or even much more than that spent by it on its own research and development;

2 A country which has already established an industrial base in various sectors of economy should take steps to

21 Spend a larger amount of money on indigenous research and development in such sectors than on importation of technology;

22 Provide incentives to local industries to make them self-reliant. Such industries should be given preferential treatment of a fiscal and financial nature, such as tax relief, subsidy etc. Such preferential treatment should be accorded to industries which intend to commercialise the know-how of a high quality developed through their own efforts as compared to other industries which have been established with imported know-how and which continue to depend for further development on imported know-how.

632 Promotion of Innovation

1 The government should

11 Formulate a policy for encouraging and supporting innovation and that this policy be carried out by institutions specially set up for the purpose, along with productive enterprises and laboratories for applied research.

12 Bring about a closer relation and cooperation between the university and the industrial community.

13 Study the feasibility and appropriateness of developing innovation research centres and promotion centres in order to formulate and implement the technological innovation policy.

14 Seek the cooperation of the top management personnel of the science-based industrial enterprises in setting up this policy.

2 The ECAFE, along with the Unesco and other agencies of the United Nations, could provide assistance in the establishment of the innovation centres.

633 Information Needs

1 The government should

11 Give priority to the development of scientific and technical information services at the national level.

12 Explore new channels and methods of exchange of information between the developed and developing countries with particular reference to the industrial application of science and technology.

2 The scope of documentation of science should cover the fields of engineering and technology.

3 The Unesco should, as it has done in the past, assist in the extension of the activities of the existing national and regional documentation centres and in the establishment of new centres in appropriate subject fields and in regions in the group of developing countries.

634 Human Resource

1 The government should pay special attention to the development of human resources needed to ensure sustained scientific and technological development.

2 The developing countries should share their experiences in planning their respective scientific and technological manpower and for this purpose, secure cooperation among themselves on a regional basis.

3 Promote the exchange of scientists and other experts between developing countries.

4 Special attention be given to the productive utilisation of trained personnel, including the provision of appropriate support personnel in adequate number.

5 Priority should be given to establish training facilities for technicians, operators, and skilled artisans. For this purpose, the cooperation and collaboration of technical institutions, industrial enterprises and universities may be secured.

635 Financial Resource

1 The developing countries should aim at reaching a minimum level of total national expenditure on research and development equal to 1 per cent of their respective GNP by 1980, if not earlier

2 Special attention should be paid to the proper measurement of the expenditure on research, experimental developmental and related scientific activities.

636 Science Policy and National Socio-Economic Planning

The government should

1 Ensure that national goals are translated into scientific missions, wherever appropriate, by the national policy-making body concerned.

2 Make available the resources needed for the research projects derived from these scientific missions and ensure the coordination of the various research projects.

3 Identify bottlenecks in human, financial, organisational or informational resources, which hamper the proper implementation of the research and development projects.

4 Make full use of the possibilities for international collaboration and assistance, in particular those provided by the UNDP and other specialised agencies of the United Nations, such as the Unesco in implementing the national research and development programmes.

5 Ensure that the long-term scientific perspective and technological forcasting are worked out on a continuing basis by the national science planning body.

637 International Cooperation in Science, Technology and Production

The governments of Asian countries, Unesco, and other agencies of the United Nations should

1 Organise, promote, and facilitate international and regional cooperation with the objective of integrating science, technology and production in the various countries of Asia, with the Unesco Regional Centres for Science and Technology playing an important role therein.

2 Arrange for more detailed collaboration in planning as well as in exchange of scientific information and experience -- through meetings of science policy experts, surveys, and study of the establishment of a regional clearing house for scientific and technical information needed for science policy planning. This will, in due course, facilitate the pooling of experiences, research facilities, resources, etc in the Asian region.

3 Investigate ways and means of pooling the scarce resources of Asian countries -- human and material.

4 Investigate the possibility of extending bilateral institutional links between countries of the region.

7 CONCLUSION

71 Information Transfer Precedes Technology Transfer

The key role of technological change as a factor contributing to the economic growth of a country is evident. Technological change, in its turn, is dependent on R and D activity. But, there is a time-lag between the generation of an idea by research and its incorporation into the mainstream of production of commodities and services. This is true of the diffusion of technology from one country to another, from one enterprise to another, as well as diffusion within a firm. Several factors contribute and complicate the process of diffusion of technology. Any information dissemination system, whether it be national, regional or industrial, which seeks to reduce the time-lag between an invention and a subsequent innovation based on it, and thereby accelerates the process of diffusion of technology between countries, between enterprises and within an enterprise, should take cognizance of these factors.

72 Need for an Infra-structure to Channelise and Assimilate Information

Today, India is attempting a fast pace of industrialisation. All her commodities should soon stand competition with those of other countries. For this purpose, our industries -- large scale, medium-scale, and small-scale -- should soon become fully based on research and know-how particularly that generated within the country. To conserve the potential of specialists in industrial organisations, every entrepreneur, industrialist, and shareholder must accept that information and knowledge are the bases of gainful decisions and of productivity. And to keep itself in the vanguard of progress, it must contribute to or make adequate provision for the selection, acquisition, organisation, dissemination, and utilisation of the information generated within the firm, within the industry, as well as from documents. All these media could be most effectively uitlised when there is a device, or agency to search for, receive, select, organise, channelise the information to the points where it will be utilised in innovative and decision-making situations. The return on the investment on such a device or agency is not to be measured merely in terms of an immediate profit each year; it should also be viewed in the broader perspective of building up an infra-structure and supporting agency for the development of the industry and of the ecnomy of the country as a whole. This is the experience of industrially advanced countries also. Gilmore and others, on the basis of investigations have pointed out that the cost of acquiring information from outside a firm in the United States exceeds Rs 18.000 per professional employee, adding the cost of overheads to salary, and including the cost of reading, telephoning, attending conferences etc.

73 A Measure of Development

The Conference Board recently pointed out: "The world computer population... is an approximate index of comparative information advantage in the world. Were we to extend this index to other aspects of the information process, such as proportion of R and D in various countries, number of professional scientists, teachers, etc and correlate this with GNP and social standards, we would find that, now, possession of various capacities to process information and operate advanced communications is a more precise indicator of relative development than many other measured indices presently in use. The "information rich" nations tend also to be materially rich with potential advantage for becoming richer; the "information poor" nations tend also to be poor in most other material respects and have least advantage".

8 PROPOSITIONS FOR CONSIDERATION

Proposition 1

The establishment of an "innovation bank' in the country to receive, register, and to disseminate information about new technical know-how generated within the country and that flowing into the country in one manner or other, would facilitate the accessibility to new know-how and coordination of technology transfer to institutions and individuals.

Proposition 2

There should be increasing emphasis on and implementation of applied research, efficient management, and adequate information facility in industrial enterprises for the purpose of creation of an environment conducive to accelerating innovation and adoption of new knowhow into the production stream.

Proposition 3

The design of technology transfer systems should take cognisance of the

a) Differential rate of transfer of technology in different types of industries and enterprises; and

b) Role of religious, educational, historical, political, economical, sociological, and scientific and technological characteristics of the giver and of the receiver of know-how, and also of the characteristics of the medium and mode of transfer.

APPENDIX 1: CASTASIA MODEL

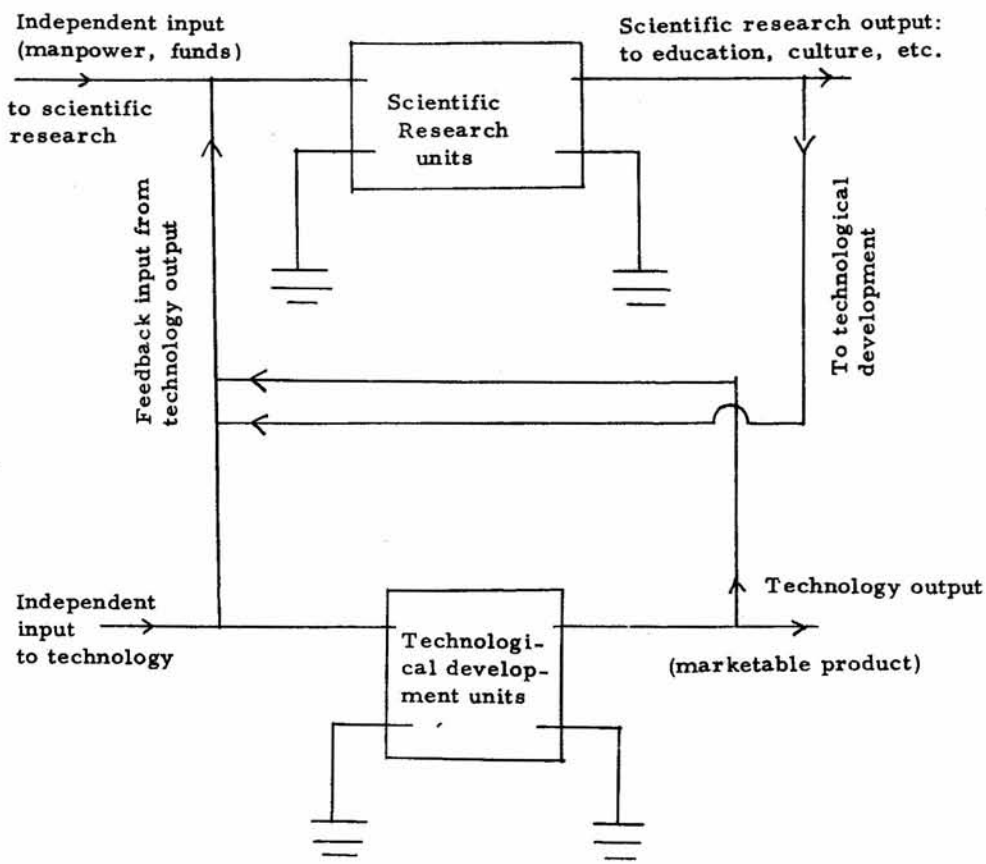

Fig. 1. Relation between scientific research and technological development: schematic diagram.

APPENDIX 2: ROGER'S MODEL

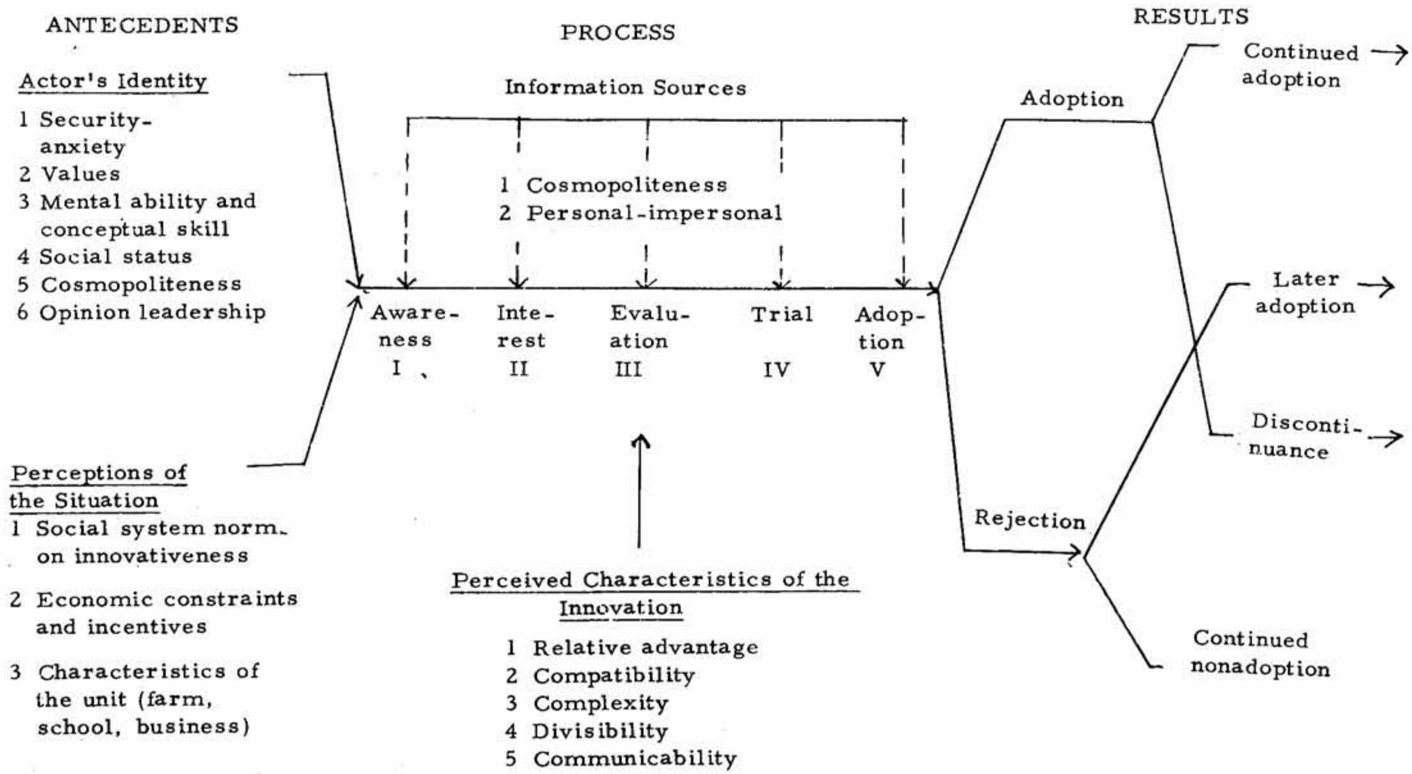

Fig. 2. Paradigm of the adoption of an innovation by an individual within a social system

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