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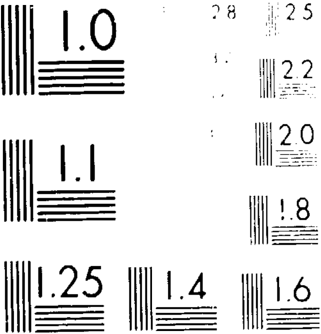
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# ASPECTS OF INDUSTRIAL RESEARCH AND DEVELOPMENT *

by

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INTRODUCTION

Modern industry cannot exist without constantly developing new and improving existing technologies. Such activity is normally referred to as the "research and development (R and D) function". It entails the development of improved and new products, of improved and new processes, of improved or new materials used in products and processes and of new and improved techniques needed in the manufacturing process, such as analytical and quality control methods and related equipment. But is this type of innovative activity really "research"? What is the difference between "research" and "development"? What is "applied research"? It is important to clarify the concepts involved in order to understand the research and development activities industry should be involved with.

Perhaps the best definition of the issues involved was given by Professor Eric Walker, president emeritus of Pennsylvania State University, during an innovation conference in Philadelphia:

> "Research and development are two quite different things. Research is the process by which we increase our basic knowledge. Pure research or basic research is done without any concern about the use which might be made of the results.
>
> Applied research is done when one finds more information is needed to continue a development programme.
>
> Development is the kind of thing that industry does. Industry has an end result in mind before it begins to develop. Development, followed by the engineering design of a product and the engineering design of a manufacturing system, brings new goods to market."

Industry then should be involved with mainly technology development and applied research, as defined above, always with a clear practical goal and objective in mind.

Since R and D costs money, it must be looked upon by management as an investment, whereby the principle of "return on investment" must also apply. Consequently, much effort has been extended in practically all industrialized countries to study the management of the R and D function itself and the literature is quite extensive. Hence, there is no need to go into details on how to manage R and D operations, how to initiate, control and evaluate projects or how to determine the cost effectiveness of R and D activities. Rather, this paper describes some new knowledge gained on another very important aspect of industrial R and D, namely its role in technology transfer.

Industrial companies not only try to develop their own, internal technologies, but also must be able to take advantage of technologies developed elsewhere and utilize these to their advantage in order to remain competitive. The issue here is not licensing, but the activity of following development elsewhere in the world and picking up those of interest and applicability to be introduced within the "home company" without resorting to licensing. This is an important task and much of the industrial R and D activity is of this nature. The best examples are the very new, fast moving technologies, such as computers and electronics, where this is easily observable: as soon as, say, a Japanese company hears or reads of a new development in the USA, they immediately try to reproduce or even improve it on their own in their own laboratories and introduce it in their operations. Naturally, this applies to other, "less visible" industries as well. This process, which is essentially a technology transfer activity, is therefore extremely important for advancing industrial technology all over the world and, by its nature, of critical importance to the developing countries.

The purpose of the rest of this paper is to describe recently gained knowledge on how this process works, particularly the role and mechanism of flow of technical and technological information as it relates to the transfer of technology, the mechanism of communication, organization of R and D activities, and the role of the human element in the progression and maturing of R and D projects. Most of the work and studies described below were carried out at the Slaon School of Management of the Massachusetts Institute of Technology in industrial corporations in the USA, and might not be applicable in all its aspects to the developing countries. Nevertheless, much of the findings are of general nature because it is based on human behaviour, and because "people are people" everywhere.

The following is based on the proceedings of an International Seminar on Management of Research and Development which the writer attended as an invited lecturer and as a participant. This summary is the essence of two weeks of lectures and discussions and is based on the writer's notes.

A. Bringing New Technology to R and D and Keeping the Organization Abreast of Current Technology (Prof. T. Allen of MIT, Sloan School of Management)

Research has shown that new information needed for solving technical problems comes to the recipient individual mainly from other people (appr. 90%), through personal contacts. Only about 10% comes from published literature through direct reading (highest in chemistry, appr. 40%). The largest portion of new ideas and information comes from outside the organization (appr. 70%) and only about 20% from within the organization. There is now consistent evidence that the better ideas come, however, from inside the organization. This includes new product ideas which turned out to be successful (90%) in the market place.

Consultants hired from outside show consistently poor performance in coming up with the ideas to solve specific problems. This then brings up three questions:

(a) why do outside consultants show poor performance?

(b) why are "inside consultants" not used more frequently?

(c) how can new ideas be brought more effectively into the firm?

One answer to the above is that technology is organization-specific. One can actually talk of a company's "technology culture". The consultant usually does not have the "feel" for this company-specific technology culture, and as an outsider he does not understand the problem.

It has been found repeatedly that when a consultant is utilized often or over a long period, he begins to understand the company and he becomes effective. With a new consultant the exact definition of the problem is absolutely essential for success.

The present general situation for utilizing inside as against outside consultants in US industry, is shown in the following table:

| Consultant | Use | Performance | Cost Benefit |
|---|---|---|---|
| Inside | low | high | high |
| Outside | high | low | low |

The reason for this situation (in the US) appears to be the fact that not enough credit is given to "assist" provided by inside consultants, as the credit goes only to the technologist who works on and "officially" solves the problem, irrespective of who has given him help. This is, therefore, a management problem and it can be overcome through properly fine-tuning the "work atmosphere" of the organisation.

Using a weekly communication questionnaire, the communications patterns of organizations could be determined with impressive accuracy (i.e. this does not only apply to R and D organizations, but to all organizations), the following very interesting facts were found repeatedly and consistently:

- (a) there are certain individuals in R and D organisations who are high communicators, and they play an important role;
- (b) high communicators were high performers;
- (c) high communicators were consistently high readers;
- (d) these high reader-communicators are frequently consulted by their colleagues for obtaining information;

The conclusion is that published literature indeed plays a most important role in the innovation process, but the information is dissipated through "carriers" or intermediaries inside the organisation.

It was also found that similar communications patterns existed between diverse organizations, with information coming in from the outside:

(a) those consulted on the outside were all high eader - high-communicators;

(b) the receivers (information seekers) were also high reader, high communicators.

Such high reader- high communicator types, are called "gatekeepers" (referred as such in the literature), and are crucial members of the organizations as technology enters through them. They are in fact "translating" the latest technical literature for "general digestion" by the rest of the members of the organization.

Gatekeepers have 3 main characteristics:

(a) they are top technical performers and recognized as such inside the organization, (i.e. only such high calibre people attract others for their advice).

(b) they tend to be at the bottom of the organization - at the bench level or at most at the first supervisory level. (This fact underlines the critical, very important role of first level technical supervisors. When these are promoted, they cease to function and are destroyed as gatekeepers. Not even "dual ladder" reward systems help, since the non-managerial advancement does not provide the decision-making power that satisfies the individual. This is a try at simulating the academic world inside business and it does not seem to work).

(c) they are visible (A note of caution is important here, in that the promotion of "pseudo gatekeepers" (i.e. inside "politicians") has a disasterous effect on staff morale, because they know and are keenly aware of the real performers and gatekeepers. One way of differentiating the real from the "pseudo" gatekeepers is by the number of publications, patents and books; the later often lack these.).

It was found that gatekeepers tend to cluster together and keep close contact with each other. This means that there exists a very strong "technical oligarchy" at the bottom of the organization that - unbeknown to management and to themselves - control to a great degree the technological destiny of the company! They in fact have an enormous "underground" power and influence on the company's operations and success. A meaningful solution still used sparingly is to group the gatekeepers into formal organizational units (i.e. task forces) and have them officially advise management.

B. Organizing for Effective R and D and Alternative Organization Structures (T. Allen)

Communication is the common, most important denominator for an R and D organization, and good communications within the organization and with the outside world is essential for success. The organization, therefore, should be such that all types of communictions are facilitated.

When looking at the functional units in R and D organizations, these are often organized along the lines of the nature of their work:

research (feasibility, exploratory)
development (advanced development, commercialization)
technical services (to sales and manufacturing)

It was found that, as the rate of the outside technological environment changes, the rate of communication of the technical service functions with the outside world also increases. Strangely enough, the exact opposite is the case with the research functions. (Note: the "rate of environmental change" is subjective, determined by "concensus measurement" within the organization).

By plotting the "mean level (i.e. average) of cummunication with the outside world" against the "rate of envirormental change", technical service shows a rising curve, while research a declining one. When the "variance in outside communications" (i.e. the difference between the communication level of the lowest and highest communicators) is plotted against the "rate of environmental change", the curve for technical service remains flat, while for research rises steeply. The explanation for this is that in technical service everybody increases its level of communication when the outside technological environment changes, while in the research functions mainly the gatekeepers react and, in their expected role, increase appreciably the level of their communication with the outside world. (This in essence means that the technical service function has no gatekeepers or that everyone acts as a gatekeeper).

The development of gatekeepers in the organization is, therefore, essential. Since they are the high performers they have to be promoted as a reward, even if their usefulness as gatekeeper is destroyed. They must, however, be replaced. It is necessary, therefore, to spot early future gatekeepers. Although it is not fully cleared as yet psychologically just what makes a gatekeeper a gatekeeper, they are easy to spot by experienced R and D managers.

The gatekeepers have two distinct roles: one inside the organization and one involving the outside world. Communications with the outside are inherent to gatekeepers and is difficult to influence. But management can help in developing the inside communicating role. It takes 2 years for the typical gatekeeper to reach a steady level of communication after joining an R and D organization. This is far too long for economically not fully utilizing his talents, and management should strive to shorten this period.

There are 2 key determinants governing internal communications:

(a) physical location

(b) work interdependency (i.e. the degree to which the nature of the work requires inputs by others and co-operation).

It is important that the new employee is placed into a location (i.e. laboratory, office), where he/she can and will have to interact with high-communicators, through whom he is brought quickly in contact with others. It is generally very advisable to put a newcomer into a position that will facilitate his quick absorption by the organization, irrespective of whether he will or will not turn out to be a gatekeeper. Research has definitely proven that the effect of the initial period of a new employee in an organization is more important than any other factor regarding his attitude toward his work and the company. Several major studies have shown that the single, overriding common factor was the rating of the initial job assignment. Those who rated their initial assignment high, were to become high performers and stayed on long with the company. The key ingredient of the job assignment was found to be "challenge".

It was found also that "task significance" (i.e. job satisfaction) parallels the "desire for autonomy" during the entire employment period of an employee, except during his initial 6 - 12 months with the company. This indicates that, while the new employee wants a challenging assignment (to enable him to show what he can produce), he is not sure of himself in the new setting as yet and wants guidance until he feels integrated into his environment. It has been shown that too much autonomy given to a beginner (just out of school) can cause extreme high levels of anxiety.

The organizational form of R and D, both structural and physical, has a major effect on overall performance. The "normal" organizational types are:

(a) functional (people grouped together based on their specialization)
(b) project (people grouped together by tasks and work objectives)
(c) matrix (a "mixture", or superimposure of the above two).

In addition, the so-called "informal organizational structure" and the actual architecture of the physical facilities and laboratories are also important.

Functional organizations work well as long as the major part of the work is contained within a single functional unit (department, section). When an interdisciplinary approach is needed, the classical functional organization runs into problems. As a result, the project organization of

R and D has developed where all the inputs (i.e. people) and specializations needed for the task are contained within a single organizational unit.

An extensive study of 39 large-scale (US $ 6 million or more) and long duration (4-5 years) projects measured the performance of the administrative and technical staff as regards achieving technical and cost-schedule objectives as a function of organization structure. It was found that:

(a) administrative personnel organized on project basis performed better in respect to cost-schedule performance; but their organizational structure had no effect on the technical performance;

(b) technical personnel on the other hand performed better when organized on a functional basis; their organization structure had no effect on cost-schedule performance.

The above suggests that the nature, size and expected duration of projects should influence the organizational structure chosen:

(a) for short duration (large scale) projects, where cost-schedule performance is particularly critical, a project organization should be the preferred choice;

(b) long duration projects, on the other hand, suggest a functional organization for best results, as the technical performance will be the rate determining step. The opposite is an often observed practice. However, as short duration (albeit large-scale) projects are carried out by functional organizations, and project organization is set up for long duration projects.

The matrix organization, (not explained further here) is successfully employed by many organizations, although there are numerous cases of failures as well. The successful mashing of project managers with the functional managers, is the key. Since this is a personality problem in many instances, the key individual, on whom the success of a matrix organization rests, is the top R and D manager who must be able to minimize personality conflicts common to such "intermeshing" organizations. It should be noted that the relocation of the project staff within the basic functional organization after the project is completed, is often a genuine problem that needs careful planning before the project terminates.

C. Architectural Design of R and D Laboratories (T. Allen)

The informal R and D organization is essentially a "communication organization" (network). To utilize fully the human resources of a company, communications must be increased and made easier as this is essential for disseminating the knowledge among the various units regarding their (technological) capabilities, and this can be achieved only through direct contact of people. Studies have determined that the degree of communication between R and D and other departments (i.e. Marketing, Production, Finance) is directly proportional to the number of people transferred from R and D into the other departments. (Note: it was found that, as a rule, reverse transfer into R and D from other departments is in most companies insignificant.) The often occuring problems of R and D with Finance is the result that practically nobody ever transfers from R and D into Finance or vice versa.

Another interesting finding was that the "high status" group (i.e. Ph.D.) communicates extensively with each other while the low status group (degree, but below Ph.D.), does not. The lower status group directs its communication towards the high status group, an undesirable trend, as it tends to cause the disintegration of the low status group. This has to be counteracted as there is need for active communication within the low status group, as well, since often knowledge on "down-to-earth" aspects of technology are located here. The elimination of status symbols (i.e. room size, desk size, furniture, drapery, etc.), is important as it strongly influences (negatively) the level of communication.

The physical location of people and their relative distance from each other has a crucial effect on communication. It was shown that the level of communication decreases exponentially with the straight line (radial) distance, and it approaches an assymptote. It was found that in R and D organizations the degree of communication was on the average at the low assymptotic level at a distance of only 50 metres. Various physical and other factors can lower or raise the curve and the assymptote, but will not change the shape of this communication-distance curve. For example, belonging to the same project team (i.e. project organization) will raise the curve (i.e. level of communication). The study of 15 major inventions has shown that (a) the gatekeepers play a key role, and (b) the key information pattern for precipitating the invention was practically superimposable on the overall communications pattern. (Note: all that was said until now about communication relates only to direct, face-to-face communication. Communication by telephone does not have the same "band width" (i.e. depth of idea interchange), and it is mainly used to arrange direct personal meetings).

From the above follows that long linear or H or L-shaped buildings are bad for communication. The R and D building should approximate a square or a circle to bring people as close as possible to each other. Tall multistorey buildings are very bad for communications. A four-storey building appears to offer the best compromise between ease of communication and economy of construction. Escalators are excellent for communications (but expensive), while elevators are bad. Wide, centrally located staircases also aid communication, while narrow stairs at the end of the building (safety stairs) are useless. The strategic location of common facilities (i.e. cafeteria, coffee machine, library, computer room, store room, etc.) also helps improving communications as people have a chance to meet.

D. Transferring Technology Internationally (T. Allen)

Until now the question of movement of information inside the firm and from the outside into the firm was dealt with and the key role of the gatekeepers identified. Consequently, the transfer of information (technology) on the international scale was also investigated in a single country. Ireland was chosen as the country for several reasons: language presented no problem for the investigators; a grant was available to finance it; and the country is not too big thus easy to survey. (Note: the case of Ireland is particularly interesting to study since in many respects Ireland can be considered as a developing country in respect of industry.) The study was rather exhaustive as about 80% of all R and D establishments in Ireland were covered. The result was that the gatekeepers were also found here and identified, just as in US R and D establishments. It should be noted that the study concentrated on identifying how technologies from outside Ireland were brought into the country.

Among all the personal characteristics of the Irish gatekeepers that were studied, such as the country of education, post graduate training, industrial experience, etc., only one common characteristic of all the "international" gatekeepers was identified: they all had extensive foreign work experience in industry. This was the only difference that separated them from other internate gatekeepers. (Note again: foreign education did not predestine anyone to become an international gatekeeper!)

The effectiveness of the foreign gatekeeper (i.e. level of communication) naturally decays with time, albeit slowly, but it can be reactivated through new foreign exposure, such as attendance at conferences, meetings, trade shows, etc. It was also found that most of the successful Irish gatekeepers regularly maintained a strong interaction with one or more gatekeepers in their work-experience country.

The study was extended to institutions (universities, R and D institutes, fairs, etc.) to identify from where the information and new ideas came from. The Table (page 13) shows some surprising results: a considerable portion of new technology naturally came through subsidiaries of transnational corporations operating in Ireland (first line in table under "parent firm"); the biggest portion, however, came from foreign companies within the same industrial sector ( not operating in Ireland, thus no secrecy caused by competition), and from foreign vendors catering to the industry. It is a little distressing to note that the contribution of universities was nil and of government R and D institutions miniscule (2%). Even industry associations and trade fairs performed better (4, 7%). (Note: the above has obviously major implications for the developing countries as well as to any technical assistance programme. The methodology of the study could now easily be extended to developing countries, and it might be very valuable to carry out such studies to determine the pattern of the inflow of technology from abroad.)

The definite conclusion is that, in order to move (transfer) technology people also have to be moved (transferred). This can be either done by first "moving" individuals of the recipient countries to other industrialized countries, to get genuine work experience in industry there, and then move them back again thus have them act as the country's international gatekeepers, or move people into the recipient country together with the technology for a considerable time. This, in fact, is what transnationals are doing.

WHERE DID THE INITIAL IDEAS COME FROM?

| ORIGIN OF THE INFORMATION | | NUMBER OF MESSAGES | PER CENT OF TOTAL |
|---|---|---|---|
| Parent Firm | | 10 | 9.3 |
| Domestic | 2 | | |
| Foreign | 8 | | |
| Firm within the same industry | | 31 | 29.0 |
| Domestic | 7 | | |
| Foreign | 24 | | |
| Firm in a different industry | | 3 | 2.8 |
| Supplier or Vendor | | 32 | 29.9 |
| Domestic | 3 | | |
| Foreign | 29 | | |
| Customer Organization | | 6 | 5.6 |
| Private Consultant | | 5 | 4.7 |
| Government-Sponsored Research Institute | | 2 | 1.9 |
| Other Domestic Government Agencies | | 4 | 3.7 |
| Universities | | 0 | 0 |
| Industry Associations and Trade Fairs | | 5 | 4.7 |
| Trade Magazines | | 7 | 6.5 |
| Professional Journals | | 2 | 1.9 |
| TOTAL | | 107 | 100.0 |

E. Project Selection Planning and Control (Prof. A. Pearson, Manchester Univ., Editor of R and D Management magazine).

The purpose of R and D (department) is simply to provide support to the organization through the provision of technology to make it easier to achieve its objectives. It should be always remembered by R and D managers that achieving company objectives is also R and D's goal.

The logical sequence assumed to operate in R and D is: basic research leads into applied research leads into development leads into pilot plant development, etc. But in practice this is not true. Some projects that start out as a purely developmental exercise suddenly lead into very basic research because some fundamental questions arise. Research and development is a continous-loop feed-back process.

For the efficient utilization of manpower, it is of advantage if well planned work programmes are established for the organizational units (departments) and subunits (sections) that are comprised of a mixture of long-term and short-term as well as research (feasibility, exploratory) and development work.

For evaluating projects to establish R and D priorities the "check list" approach listing various factors influencing the decision, is very valuable. Next to general points reflecting on financial desirability and probability aspects, it is essential that the check list also contains elements that are specific and important to the company. Literature on this subject is extensive and elaborate.

F. Strategy Formulation (Prof. B. Quinn, School of Business, University of Maryland.

The role of R and D is often critical for the development of business strategy, and it must be clearly defined. (The mechanism on how to develop such business strategies was demonstrated with a case study, whereby the integration of the R and D into the strategy was stressed). It was shown that the following aspects are of particular importance:

(a) the overall company strategy has a critical effect on R and D inputs and individual project priorities; these priorities cannot be based purely on financial considerations (i.e. return on investment);

(b) first, the macro strategy and the required R and D inputs for each macro component (e.g. product line; geographical area; new ventures; licensing objectives; etc.) has to be determined;

(c) after this is accomplished, project priorities, i.e. micro strategy, for each macro component have to be determined separately. Even a non-profit-making product line or venture needs R and D support if it is pursued within the framework of overall company strategy for whatever reasons. (Note: this last point is often not understood by the financial functions of the company, who tend to put all projects into "one pot" and determine priorities for the entire project portfolio on financial considerations only. This approach has to be resisted and avoided, otherwise the R and D stategy will not fit with the overall company stategy.)

G. Critical Functions in R and D (Prof. E. Roberts, Sloan School of Management, MIT)

The "critical functions analysis", a relatively new concept assumes that of the three levels of R and D functions, namely (a) top management, (b) middle level of management, and (c) the research personnel (i.e. "troops") top management in reality concerns itself with other matters than its principal functions, namely R and D policy and strategy formulation, personnel management, conflict resolution, etc. In fact, these genuine management activities consume only a small part of top managers' time as organizations normally "run themselves" based on precedents. But top managers perform other types of nonmanagement R and D functions that are critical to the success of R and D operations. These other functions are to a large extent non-formalized functions that are important in the lifecycle of projects. All these different functions have been recognized and studied in the past, but looking at their role in an integrated fashion is what "critical function analysis" is concerned with.

The critical functions in industrial R and D are the following:

(a) the creative scientist or engineer - these are the basic problems solvers who regularly come up with new technical ideas;

(b) gatekeepers - at times also doubling as creative scientists, stay informed and relay information to their colleagues in relation to their problems; it should be noted that there are also "market gatekeepers", who perform the service of advanced market information;

(c) "entrepreneur"(internal to the company) - a pusher of ideas, enthusiastic individuals who generally enjoy development work as opposed to (basic) research;

(d) project manager - organizer of multiple inputs and contributions; sensitive to people; enjoys decision preparation and decision making;

(e) sponsor - from upper levels of management, but not direct supervisor, rather from other functions (i.e. sales, production, etc), who believes in the idea and helps the"entrepreneur" to move his idea ahead, these are usually senior, experienced individuals who enjoy helping others.

N

There exists no definite test to predict creativity. But it was found that people who recognize problems tend to be technically also more creative in solving them. It was also found that a mixed work environment, where the same individual was carrying out research as well as development work in various fields, increases creativity.

The entrepreneurs (idea exploiters) are on the other hand quite different from the idea generators (creative problem solvers). It was found that in the US (and Western society in general; other societies were not investigated) the entrepreneurs tend to be first born sons, (such as all US submarine commanders in World War II). The entrepreneur is essentially an idea pusher and his character is determined to a great degree by his cultural background. (For details see the book of McClellan titled "The Achieving Society", Van Nostrand.).

People with this entrepreneurial character are also essential inside companies because these are who convert ideas into practical use. One of the characteristics of such "idea exploiters" or entrepreneurs is that they are much more aware of potential financial support than others within the organization. The availability of such "idea pusher" inside the company are critical for transferring technology from R and D into practical use, either to the market as a new product or into manufacturing as a new process. (Note: it is possible that the same holds true for transferring new ideas from one country to the other).

H. Dynamics of R and D Allocation (E. Roberts)

Technology development passes through definite, distinct phases:

(a) the research stage - difficult to measure or evaluate as it is very intangible; it also tends to be of long duration, low-input rate activity;

(b) once a research idea has been proven feasible, it moves into the development stage - this phase is much more tangible, measurable and is also usually much more costly;

(c) after successful completion of the development stage, it moves into the commercialization ( advanced development, pilot scale stage - this is naturally the most tangible, measurable and costly stage.

There is a definite "pull" of R and D funds resources and people towards the development and commercialization activities as these can be easier measured and justified. Because of the difficulties involved at justifying R and D activities at the research stage, in many companies true research activities are non-existent and most R and D work starts at the development stage.

This drawing power of the "down" stream" stages of R and D activities is most important to recognize, because it's a main cause of "cyclization", meaning that by the time the commercialization of a major new development is completed, most of the R and D resources are concentrated there and research becomes "bare", with no new development coming along. At this point the redeployment of staff into research has to take place in order to generate new ideas for future business opportunities. (Actual case example: the Polaroid Corporation).

Because resource allocation in R and D operations often is not proportioned to the various stages of research and development, "down-stream pull" occurs leading to the cyclic effect. In short-cycle type of R and D work, such as in a single product line, multi-product company, this cyclization is less noticeable and can be evened out through allocation of projects at different stages among the staff. But in business requiring long-range R and D work, such as in chemicals, pharmaceuticals, systems companies (e.g. IBM, Xerox) this cyclization and its avoidance is a critical issue for the long-term growth of the company.

It should be recognized that the most important, intangible capital of a company is what is referred to as "know-how" and it comes from all phases of technologicalresearch and development work. It is essentially the pay-off for a company being actively engaged in research and development.

## I. Transfer of R and D Results (E. Roberts)

By now it is clear that technology development moves through distinct phases and during each phase different types of functions become critical for achieving success. During the research stage it is the creative scientist and the gatekeeper who is needed during the development stage the entrepreneur and the sponsor; during the commercialization stage the entrepreneur and the project manager. All these functions can be held by the same or more individuals during each phase. There are even rare cases where the creative scientist moves along with the project and becomes successively the entrepreneur, project manager and finally the manager of the new venture after it is successfully commercialized.

The critical factors for facilitating technology transfer inside the organization over interfaces (R and D to Sales; R and D to Manufacturing) are:

(a) early appointment of a project manager;
(b) early involvement of R and D management;
(c) a visible and committed "transfer manager";
(d) favourable economic analysis for the project;
(e) sufficient patent protection.

Movement of personnel also helps interface technology transfer:

(a) from receiver into R and D prior to transfer;
(b) from R and D to receiver (on loan) when the project moves.

Providing the essential project skills required was found to be essential for success as well;

(a) research skills (intricate technological knowledge);
(b) project manager being knowledgeable on the application of the transferred technology;
(c) engineering support capability.

In terms of strategic factors that were important in facilitating and speeding up the transfer:

(a) outside pressures on receiving unit (e.g. company "legislation");
(b) clear identity of "target market" before the transfer;
(c) internal dissemination of information on project (internal R and D "public relations");
(d) novelty of invention, as long as major operational changes are not required;
(e) courageous, tenacious inventors.

Since many of the very productive "idea generators" and creative scientist are often neither courageous nor tenacious, these quiet but very productive individuals need special attention on the part of R and D management in order to foster their creativeness and channel it in the right direction.

J. Corporate Management of New Ventures (E. Roberts)

This is a special aspect of the commercialization of new R and D developments, where these represent an entirely new business area, or a new technology and thus become a distinct new business unit with its new organizational form. History shows that a very high probability of failure is the rule, and this has to be clearly recognized by management.

There are various strategies and methods for getting into new ventures, such as venture capital, venture spin-off, joint ventures, and internal ventures. (These are not explained further here). The reason for the different approaches lies mainly on the nature of the new technology.

Patent licensing is one of the least promising approaches. It was shown that 99.6% of all patents licensed generated less than a total of $ 100,000 income. Technology (know-how) licensing, on the other hand, is the most profitable form of licensing. This truly shows the value of the "know-how" capital of a company that is essentially generated through research and development.

K. The Challenge of Post Miracle Japan (T. Mende, CEI Faculty Member, Author of many books and publications)

This lecture, while mainly dealing with socio-political analysis, was most interesting and made two important points related to R and D and technology transfer that are worth mentioning, as these are thought to be key positive factors for the tremendous industrial development of Japan explaining the phenomenal success of the country for transferring technology:

(a) starting around the turn of the century and lasting until very recently, a tremendous amount of world technological literature was translated into Japanese and thus made accessible for the technologists and researchers of the country:

(b) after World War II a large number of Japanese technicians were sent abroad to study and gain industrial experience. In order to ensure that these technicians returned to Japan after completion of their overseas tour, they were not too young (around 40 years of age) and had families in Japan who stayed behind. This of course, ensured their return. (Note: this way Japan actually developed a cadre of "international gatekeepers".).

## EPILOGUE

In conclusion, it should be emphasized that because of its intangible nature successful industrial R and D, its operations and management is a very complex issue. Top managers must recognize that it is not sufficient to build a laboratory and put scientists in it and assume that innovation will automatically result. There is a history of many companies in the industrialized countries spending large amounts of money on R and D with relatively little to show for it, while other companies are great innovators with much less funding. Certainly, industrial research and development will have to play a major role, including in the transfer of technologies, in the coming years in the developing countries to strengthen their industrial base and economy and pave the way for improving the quality of the life of their people.