THE MANAGEMENT OF TECHNOLOGY TRANSFER
Plenary Paper[1]

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Technology today is one of the most powerful forces in our environment and at times it is by far the most important for many firms, institutions, nations and society at large. And its power is still growing.

James R. Bright (1972)

Knowledge, during the last few decades, has become the central capital, the cost centre and the crucial resource of the economy.

Peter F. Drucker (1969)

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ABSTRACT

The future world economic development as well as the improvement of other aspects of the quality of life depends to a very large extent on technological development, which again depends essentially on the successful application of the process of technological innovation. This process with its various stages of research, development, engineering, and marketing cannot function without effective communication for the purpose of technology transfer, i.e., transferring knowledge between the stages.

It is important not only to understand the process of technological innovation and to realize that technology transfer is an essential part of it, but also to understand that technology transfer is the transferring of knowledge rather than of goods and services, and is dependent on successful communication. Further, technology transfer should be managed as part of the package of managing technological innovation, which should be purposeful and continuous rather than a response to haphazard demands.

One of the aims of the National Timber Research Institute is to promote the more efficient use of the South African wood resource as a reliable and economical structural material. Research results in this field have been successfully transferred to the South African forest products industry where 90 low cost stress-grading machines are now in use, and where stress-graded timber is selectively used in glulam products and 20% of all roof trusses.

The low cost grading machine, the grading system, the design data, the roof truss design method and computer program, as well as the glulam manufacturing systems, were developed by the National Timber Research Institute and transferred to industry by way of research steering committees, symposia, publications, industry-sponsored development contracts, and direct assistance in factories.

Keywords: Economic development, technological innovation and transfer, research, management.

INTRODUCTION

In the above two quotations lie locked the power, the opportunities, and an immense challenge for future economic development and improvement of other aspects of the quality of life. The power of developing new technology, the opportunities to exploit the knowledge people have of technology, and the challenge

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to people to plan and manage the exploitation of this power is the subject of this paper. The aim is to describe one model of technological innovation, i.e., the system of developing and applying technology through people and to show that technology transfer by people and purposeful management by people is a prerequisite for the success of the system. Certainly a better understanding of the system of technological innovation will assist with improved technology transfer and application of research results.

All research people are a part of this system, as are most technical educators and a large number of engineers and managers in industry. Technology transfer provides the flow link of knowledge that is a prerequisite for the operation of the technological innovation system, and management provides the driving force to achieve maximum success.

This new perception of technology and its transfer or application puts the opportunities to be exploited in a new perspective, calling for new priorities to be set and to be followed, so leading to the achievement of wider horizons than we ever dreamt of in the past.

To achieve our aim we have to get a clear picture of the historical role that technology played in the development of the world economy, and also of its importance to the future. A close look at technological innovation is required to enable us to understand the process of development, transfer, and economic application of technology. It is essential to understand that technology transfer is the communication process that links the people who operate the various facets of technology development, transfer, and application; and planning and management are as important to the success of technology transfer as they are to any other business venture. Finally, the system depends on people. In fact, apart from funds, people are the main resource in technological innovation. The ideas that form the basis of all research, development, or innovation originate in the minds of people. The initiative, drive, and determination required to develop ideas into successful economic application can only come from people who are motivated to achieve a particular goal (Bosman 1977).

THE INFLUENCE OF TECHNOLOGY ON ECONOMIC DEVELOPMENT

The economic expansion during this century is based on technologies that were firmly established before the First World War and that exploited inventions made in the previous fifty years. For example, farming is the main force behind the economic growth in developed countries, and farm productivity in most developed countries has been increasing faster than productivity in the manufacturing industry. Although agricultural technology is continuously improving, most of the important basic developments, such as tractors, fertilizers, and improved seeds and breeds, were initiated at the beginning of this century or in the latter part of the previous century.

Similar arguments hold for the other important forces in the economic expansion, i.e., the steel industry, the automobile industry, the electrical industry, and the organic chemical industry. All these industries are based on technology.

There are also many other new industries based on newer technologies, but in terms of economic importance, i.e., by contribution to national product and employment, they are still relatively small. Some are, however, growing fast, such as plastics, aircraft, and computers; and they can be expected to play a major role in technological and economic development in the future.

So much for history, although the last paragraph has already brought us to a transitional stage between past and future. According to Drucker (1969), in this transitional stage the world is experiencing and will experience, to a growing extent, a major discontinuity—a drastic "shift" to industries based not only on new and different technologies, but on different sciences, different logic, and a different perception. He is convinced that these new industries will demand "knowledge" workers rather than manual workers in contrast to the industries of the past. This indicates not only a demand for technological innovation, with all its facets and at a much higher level than in the past, but also a demand for the transfer of this technology on a much bigger scale to many more workers than ever before.

These new industries have the capability of providing rapid economic growth for a long time to come. The old industries, although they may still grow and prosper relative to their past achievements, are expected to increasingly lose their capacity to contribute to rising national incomes and employment.

TECHNOLOGICAL INNOVATION

Technological innovation is the main force behind technological development. It is the process of applying scientific, engineering, manufacturing, marketing, and managerial functions to develop an idea or an invention in order to achieve industrial and commercial objectives.

Charpie (1970) classifies technological innovations as follows:

- those that bring about productivity gains;
- those that represent new contributions to existing products, processes or industries; and
- those that express themselves in the spectacular creation of completely new industries.

He continues that many studies in industrialized countries show that 30 to 50% of long-term economic growth stems from technological innovations that improve productivity, and approximately the same amount from technological innovations that lead to new products, processes, or completely new industries.

Bright (1971) describes (Fig. 1) eight stages or phases in the process of technological innovation, although there could be as few as three and as many as fifteen. The stages, although not sharply defined, are readily identifiable and facilitate measurement and comparison. The first stage is the scientific suggestion, discovery, or recognition of a need or an opportunity. It appears that the bulk of contemporary and recent innovations do not originate in undirected basic research activity, but spring from the recognition of a need or the recognition of an opportunity. The next stage covers applied research and development, followed by the industrially oriented stages of the manufacture of prototypes, tooling for production, etc. until a commercially successful series of products is accepted and taken up by the market. Generally a linear program is followed, though provision is often made for feedback of information from a later phase to a previous phase. Twiss (1974), in a very lucid analysis (Fig. 2), shows how information

Stage	Identified by	Comments
1	Scientific suggestion, discovery, recognition of need or opportunity.	The latter source seems to be the origin of the majority of contemporary innovations.
2	Proposal of theory or design concept.	Implying the crystallisation of the theory or design concept that is ultimately successful. Usually the culmination of much trial and error.
3	Laboratory verification of theory or design concept.	Demonstration of the existence or the operational validity of the concepts suggested in the previous stage. May be difficult for the manager to assess since the thing demonstrated usually is a phenomenon, rather than an application.
4	Laboratory demonstration of application.	The principle is embodied in a laboratory '*bread board*' model of the device (or sample material, or its process equivalent) showing the theory of Stage 2 reduced to a hopefully useful form.
5	Full-scale or field trial.	The concept has moved from the laboratory bench into its first trial on a large scale. A succession of prototypes follows, leading eventually to a saleable model.
6	Commercial introduction or first operational use.	First sale of an operational system. This may be deliberate or unconscious premature application of the previous stage; and so be replete with debugging problems.
7	Widespread adoption as indicated by substantial profits, common usage, significant impact.	Admittedly, this stage is not sharply defined. An individual firm might choose to classify this as recovering its R & D investment through profits on the sale of the innovation, or simply the achievement of profitability.
8	Proliferation.	The technical device is applied to other uses; or the scientific principle is adapted to different purposes. This activity often begins at an earlier stage.

FIG. 1. Stages in the process of technological innovation according to Bright (1971).

is fed in continually from the research and development groups, as well as from the marketing division, to the project team.

Loubser and Le Riche (1979) are of the opinion that the full picture of the interaction taking place during innovation can best be described by a matrix as shown in Fig. 3. In this matrix it is important, as a starting point, to distinguish between the chronological phases of especially large projects whose initiation and peak efforts follow one after the other, although they may run parallel at times. Phases are set out horizontally in Fig. 3. There are also different functions, quite apart and distinct from the phases, which cover the specific tasks that must be carried out to complete the innovation process. Functions are shown vertically in the figure. The phases and functions differ, depending on the type and size of the project. This is an interesting new conceptual view of the process of technological innovation, which has communication as one of the functions.

Loubser and Le Riche (1979) further describe how technological innovation is often considered as synonymous with technology transfer. This is also evident from the Proceedings of the Symposium on Technology Transfer (1974) which was attended by 180 delegates in Pretoria during 1975.

At this Symposium a Nominal Group Technique was used to clarify conclusions and to weight priority selection of all conclusions. With the use of closed-circuit television and a mini-computer, the conclusions and recommendations were immediately listed according to the priorities set by the participants and were discussed again during the Symposium.

The delegates strongly stressed the need for research to be directed at industrial requirements. They indicated that technology transfer will succeed only when it

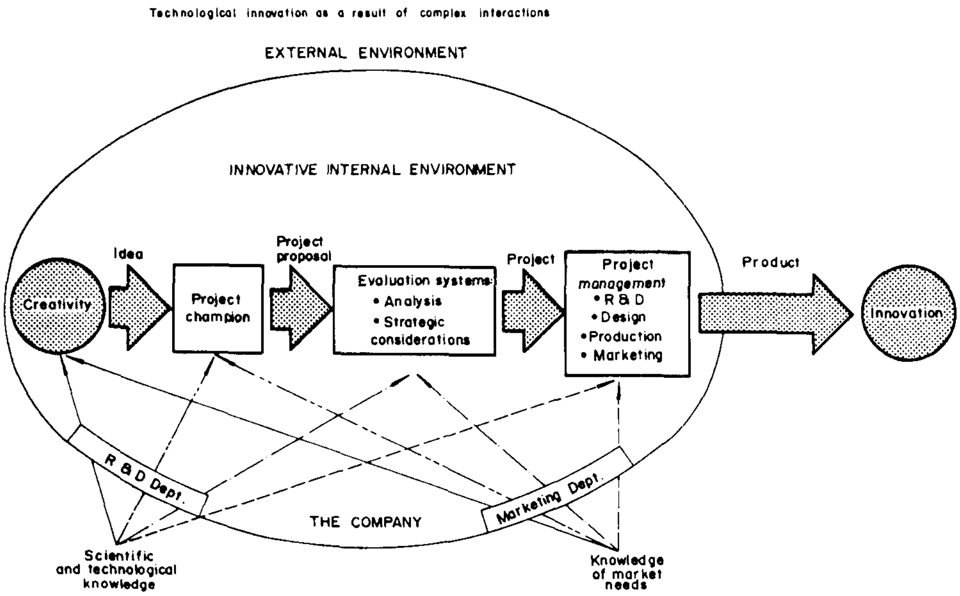

FIG. 2. The Technological Innovation Process according to Twiss (1974).

is directed at industrial and social needs and is assisted by effective push. The delegates found that there is a communication gap between research and industry, and that personal communication between scientists and factory personnel is necessary to bridge this gap.

The delegates stressed that technological growth is essential. They also felt strongly about the need to investigate and improve technology transfer in South Africa, and considered that industries should not only purchase technology that is already available, but should also develop their own technology. In this way they could profit by their own efforts and by the efficient use of transferred technology.

They considered the directing of a science policy, including research expenditures, towards development rather than pure and applied research, to be very important. They also strongly favored a marketing approach for technology transfer, which included keeping industry up to date on available technology. Other aspects that received high priority were the assignment of specific responsibility for technology transfer to particular institutions and individuals; the exchange of staff between research training, and industry; and an efficient technological information system. Within the research environment it was considered necessary that scientists operate in interdisciplinary teams.

Other recommendations stressed various aspects of technology transfer such as an understanding of the role and development of technology, staff attitudes to technology transfer, and the importance of new technology as a solution to rising labor costs and raw material scarcities. The delegates, however, also added an important condition to industry-directed research, namely that such research should not exclude basic research on new ideas that will serve as the foundation for future industrial technology.

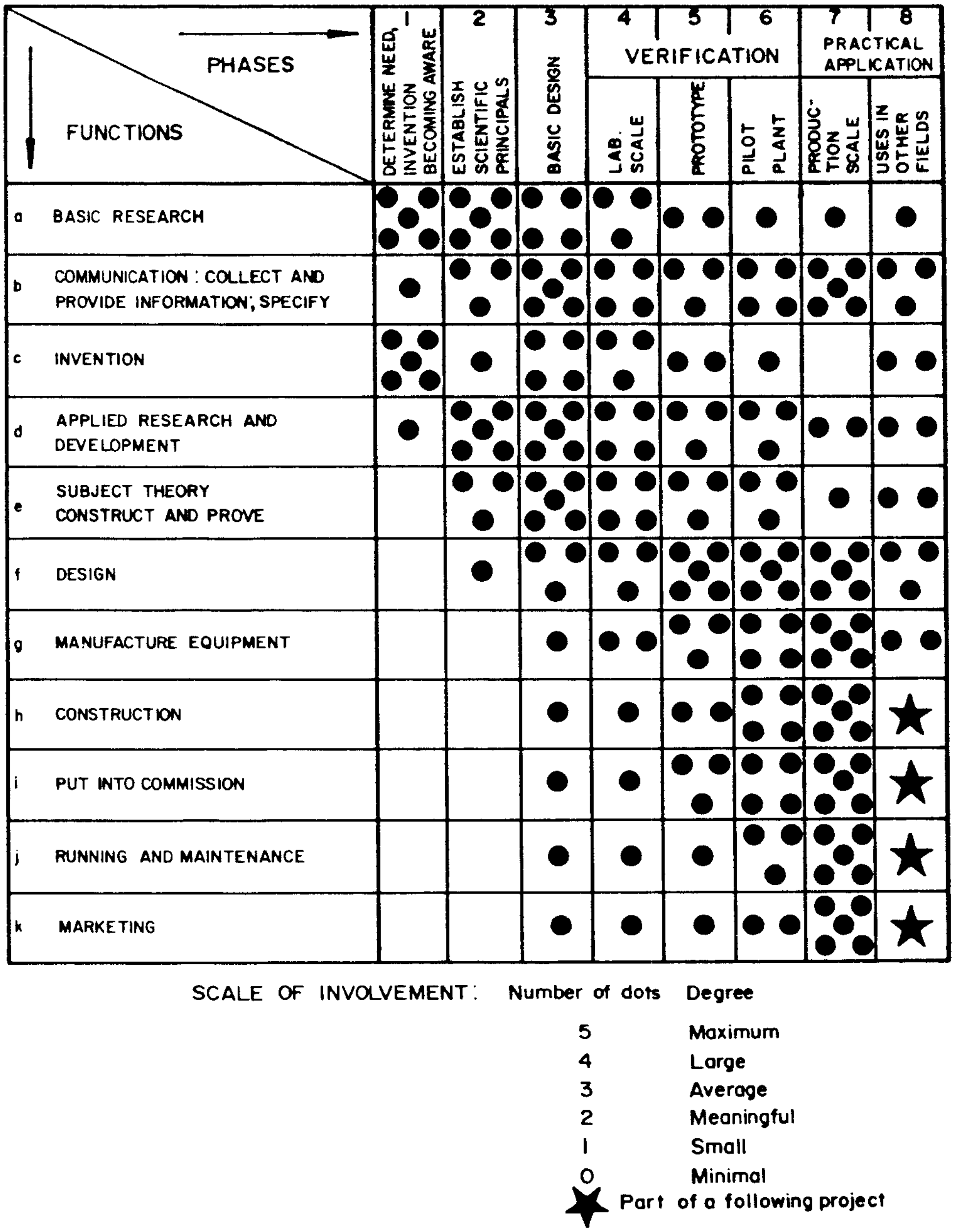

FIG. 3. Typical involvement of functions at each stage of development of a large project.

Although these findings are considered as most important, since they are the summarized, weighted opinions of 180 people directly involved in this field, it does not seem, for a clear understanding of the subject, and for purposeful technology transfer, that sufficient distinction was made between the subject of technology transfer and technological innovation.

Bosman (1969) introduced an article on "Research and development—a prerequisite for economic progress in industry" with the following four paragraphs:

> If any group of people today is asked the question 'What do you think are the two most dramatic events during recent years?' the reply, with very few exceptions, will be "The first successful heart transplant in Cape Town" and "The first successful landing on the moon."
>
> These two events can be seen as the culmination of two of the most far-reaching research and development projects of all time, and it is difficult for us to imagine that any two people could be more famous than Dr. Chris Barnard and Mr. Neil Armstrong, who played the leading roles in these events.
>
> Two important aspects of research and development emerge from the above statement that these two world-shattering accomplishments of man are the climax of research and development efforts: the first is that research and development are essential ingredients of all outstanding modern technological developments; the second concerns the size of the projects—in the first case a very small team achieved the success, while in the other the biggest research and development machine in the world was used, employing many thousands of workers ranging from the most outstanding and most highly qualified engineers to the lowliest technicians.
>
> This indicates that with effective management and with special reference to proper motivation and training, and by making use of international communication or technology transfer, and the effective application of technology, success is not dependent on the size of the team—on the contrary, a small team can often play a leading role in important technological developments. Today, virtually all industrial or other undertakings are in a position to make use of research and development in an endeavor to achieve their aims.

Ten years later, the argument on the importance of the application of technology to economic progress is even stronger if we think of the efforts to solve the worldwide energy problem as well as the detrimental effects of some of the more important technological applications, e.g. the noise levels of jet aircraft, and the possible pollution problems caused by chemical factories and by atomic energy power stations.

We are thinking here of chemical, radiation, sound, and heat pollution, which may even be followed by psychological pollution, e.g., unethical advertising that now may still be thought to be in the realm of science fiction.

The second point concerning the size of research projects is certainly also still valid. It is not necessarily the big organizations or the big projects that are most successful. Holt (1978) states that it is often claimed that large firms are not innovative. Such firms are usually well equipped for handling current operations. However, they often run into problems when attempting to master the change process by innovative behavior. According to Levitt (1968) the larger the company, the more all new ideas are screened. This almost invariably kills all but the most obvious and the least risky. Dailey (1967) says that in contrast to the entrepreneur who sees his organization as an instrument for change, the professional manager has a bureaucratic attitude and sees his organization as an impersonal machine governed by rules and policies.

A comparison of the systems described here, and in other publications, shows a divergence of the understanding of technological innovation and the transfer of technology. It varies from being seen as completely separate but complementary systems, to being different names for the same system.

One must expect that each scientific writer who deals with the subject of technology transfer will develop a model or understanding around his own experience and his own circumstances. This is quite natural and the set aims can be achieved within the set boundaries. To broaden the scope of such a model to cover all circumstances is probably possible, but certainly impracticable. It does, however, seem possible to develop a model that goes much wider than the usual and also to distinguish in this model between the process of technological innovation and the role that technology transfer plays within this process and outside it.

It is therefore important to know the difference between technological innovation and technology transfer. Technological innovation is defined as the development and economic exploitation of a product, a process, or a service from the idea to the marketing phase. Technology transfer, on the other hand, is defined as the transferring of the available information of products, processes and services, or of their development rather than the transferring of the products, processes and services themselves.

Figure 4 shows a model of technological innovation based on all the above arguments and with phases and functions as suggested by Loubser and Le Riche (1979). When looking at the figure globally and remembering that the area of each block shaded is directly proportional to the involvement between the phases and functions, one can see that there is a field of maximum involvement diagonally across the diagram from left to right. This indicates that the first phases correlate strongly with research and development while the last phases correlate with the last functions, such as marketing. This correlation is part of the reason why in many publications, phases and functions are described as synonymous and this leads to an oversimplified linear model. Since people perform the functions, the model (Fig. 4) also shows the relationship between the research, engineering, production, marketing, and management staff, and the functions of the technological innovation model. Communication is shown as a link between all staff and should be continuous. In this model communication between staff is really technology transfer within the process of technological innovation.

TECHNOLOGY TRANSFER

Teece (1976) defines technology transfer as the process of transferring from one production entity to another the know-how required to utilize a particular technology successfully.

Technology transfer in the private or public sector can be viewed as a process that involves the linking of technologies at one extreme with expressed or innate needs at the other end by means of a complex brokerage system. This process of transfer has been identified by the USA Department of Commerce (1974) on Technology Transfer and Utilization as consisting of the following steps:

- Collecting, or organizing and storing the results of research and development (R&D) i.e. the technology.
- Publishing and disseminating the R&D information.

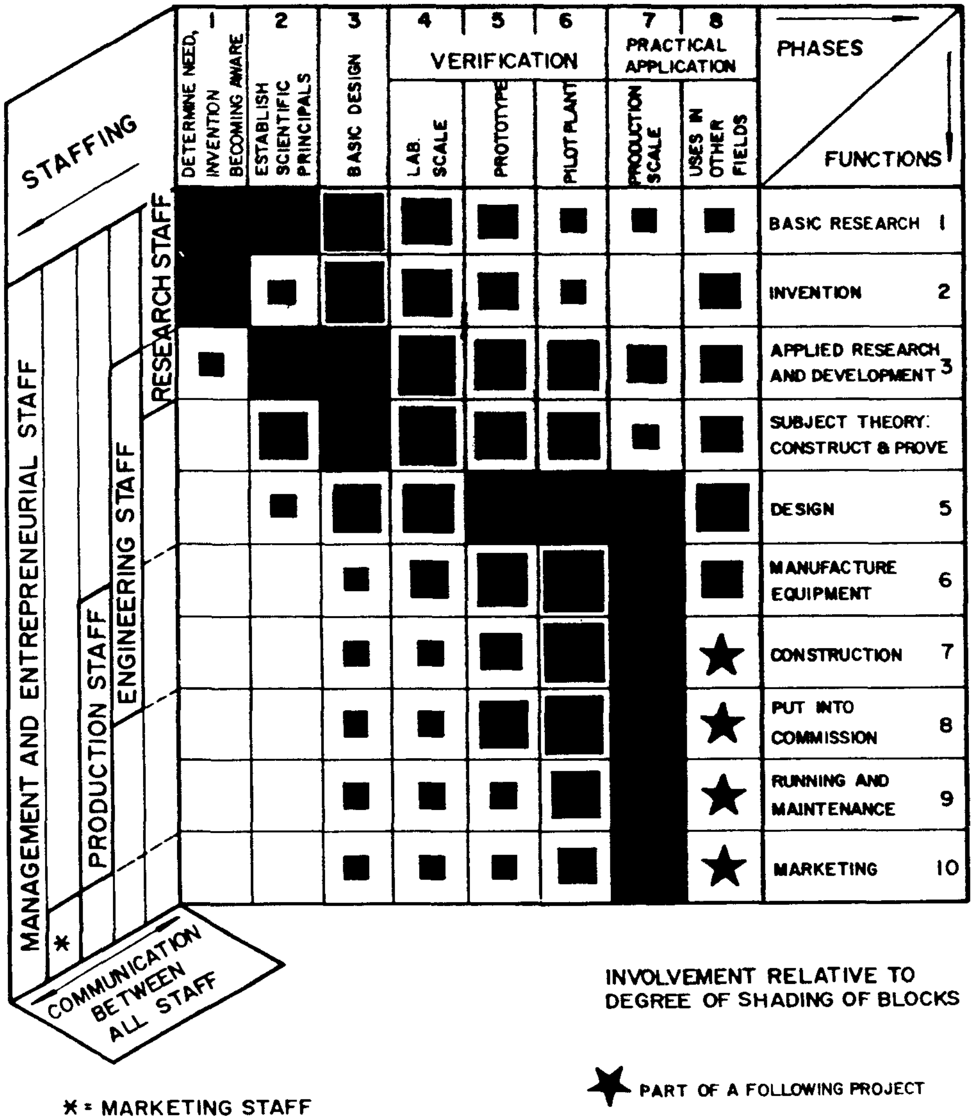

FIG. 4. The process of technological innovation.

- Identifying a need and evaluating the technological requirements that must be met to satisfy it.
- Matching of the available technology with the specific need or ultimate use with the aid of the potential users.
- Defining the market potential and other parameters that should help to determine the potential utilization.
- Examining the possible consequences that may result from fulfilling the needs and their impact.
- Locating the potential "suppliers" who are able and available to translate the technical information into practical reality.

· Determining the resources and other requirements necessary for suppliers to produce the product, service, or process.
· Associating the suppliers and users so they can agree on the standards, characteristics, performance, and constraints of the product, service, or process.
· Performing the adaptive engineering necessary to develop the product or service or to acquire any missing elements.
· Establishing a business or implementation plan to determine production and operation costs.
· Acquiring the necessary financing.
· Creating a marketing plan, production of the product, service, or process and implementation of its sale at a price a purchaser will pay.

Gartner and Naiman (1976) suggest that to apply the above process of technology transfer successfully requires

· the setting up of specific and consistent goals and policies among parties involved in the transfer;
· the adherence to specific criteria developed for technology transfer;
· the development of a formal structure to bring the stated goals to fruition;
· the minimization or elimination of barriers of the transfer environment;
· the designation and existence of an individual or individuals to oversee and co-ordinate the transfer process.

As indicated in the model of technological innovation in Fig. 4, communication between staff is an important function but is in effect really technology transfer within the process of technological innovation.

This is called vertical transfer of technology. When information on products, processes, or services is transferred from one group working on a technological innovation to another technology innovation group, horizontal transfer of technology takes place (Fig. 5).

Özdas (1979) defines technology transfer as a complex dynamic process that starts with the conception and creation of new knowledge and techniques, and continues with their successive application and utilization. In a limited two-dimensional context, we can imagine a vertical transfer existing when scientific or technical knowledge develops as a continuing process, during which it is broadened or receives inputs from several external sources, resulting in the new application of knowledge or technology techniques. Horizontal transfers occur when there is a transposition from one area of application to another, or when alternative opportunities for use arise, or when the technology is exported to a different social, political, technical, scientific, or economic environment.

As indicated in Fig. 5, technology transfer must be seen not only as transfer from one formal innovation group to another similar group, but it can be the transfer of information on a product, process, or service on any scale to any person working alone or as part of an organization.

The important point stressed here is that information on products, processes, and services transferred to any person that uses the information, however small or big the scale, is, in effect, transferring technology, or as it is often referred to by research people, is the application of research results.

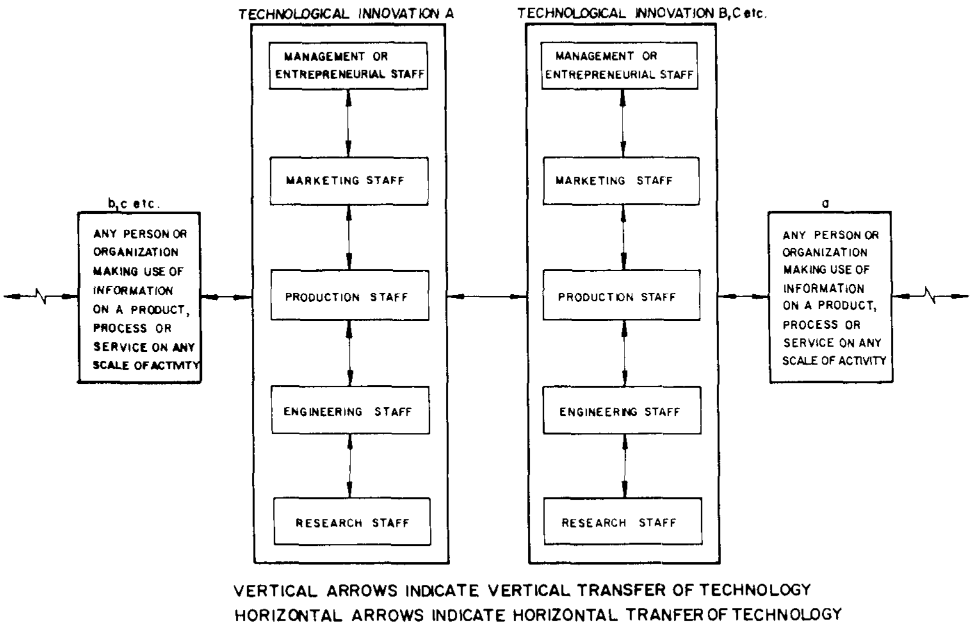

FIG. 5. The process of technology transfer.

As was stressed earlier in the paper, it is important to plan for the transfer of technology and also to manage this transfer to ensure the most effective use of the research results or the most successful technological innovation.

Research people in the past tended to see themselves as part of the academic fraternity, which may still be true for some university staff and, in rare cases, for research staff of government research organizations. In the last ten years things have changed (Bosman 1977) and all research workers are continually being threatened to produce if they do not want to perish. Unless copious applicable research results are forthcoming, leading to economic advantages, research funds will dry up. As this condition worsens all research staff will, to an increasing extent, be forced not only to produce more research results, and more quickly and more relevant, but they will have to be involved in the transfer of their new technology, i.e. the application of their results.

The President of the United States expressed an interest in technology transfer (Message to Congress 1972):

> In the first place, we must always be aware that the mere fact of scientific discovery alone is not enough. Even the most important break-through will have little impact on our lives unless it is put to use—and putting an idea to use is a far more complex process than has often been appreciated. To accomplish this transformation, we must combine the genius of invention with the skills of entrepreneurship, management, marketing and finance. Secondly, we must see that the environment for technology innovation is a favorable one. In some cases excessive regulation, inadequate incentives and other barriers to innovation have worked to discourage and even impede the entrepreneurial

spirit. We need to do a better job of determining the extent to which such conditions exist, then underlying causes and the best way of dealing with them.

Gartner and Naiman (1976) state that in spite of this expressed interest in technology by the President, expenditures on technology transfer have been relatively small. In 1973 $17 billion was spent by the U.S. Government on research and development, $1 billion was spent on collection, organization and descriptive information, while only $43 million, 0.25 per cent of the total research and development budget, was allocated towards technology transfer.

It seems obvious at this stage that the most effective step that research people, engineers, and managers can take to become more successful is to transfer technology more efficiently. This is stated since it does not seem possible to improve the quality of the research or the generation of technological information to any great extent.

An example of the technology transfer during the development of a stress-grading system in South Africa is given as the last part of this paper to show how technology transfer took place continuously during the process of technological innovation and how the management of the transfer of technology was part of the project management during the complete process of technological innovation.

MANAGEMENT OF TECHNOLOGY TRANSFER

Technology transfer is normally part of the process of technological innovation. It cannot stand on its own and the aim should be to improve technological innovation. Technology transfer should therefore be managed as part of the package of managing technological innovation, but this management should be purposeful and continuous rather than a response to haphazard demands.

The following (Bosman 1973) is a technological innovation management process of three phases and eight functions that can be used as a guideline in working out a process to serve any particular purpose.

THE PROCESS OF MANAGING RESEARCH AND DEVELOPMENT FOR THE ACHIEVEMENT AND APPLICATION OF RESULTS

Phases	*Functions*
I	
Formulating objectives	1. Formulating realistic objectives of maximum advantage to organization
II	
Management of research and development projects for the achievement of results	2. Planning 3. Organizing 4. Staffing 5. Directing 6. Controlling
III	
Application of results of research	7. Dissemination of results 8. Assisting industry and consumers with practical application of results

Technology transfer, as indicated in Fig. 5, is also the transfer of knowledge from an innovation process to another innovation process or to any individual person or organization. When the transfer takes place across the boundaries of a formal organization, management becomes more diffuse and difficult but certainly not less important.

This brief introduction to a management approach would be sufficient for most research managers of today, but some research workers do not realize that a major change has taken place in the last ten years. Bosman (1977) stated:

> Things have changed and now all research workers are continually threatened to "produce or perish." Unless copious applicable research results leading to economic advantages are forthcoming, funds will dry up. More and more rigorous controls are set up to ensure high returns on research investments. It is of great importance to research workers to know about this change—what caused it and how their future is likely to be influenced by it.

This paper is not aimed at research management *per se* but three important points should be made. First, the purpose of managing should be seen as stressing the responsibilities of people and focusing their effort on coordinated performance in contrast to "doing one's own thing." The second point is that where technology is transferred between organizations, it is dependent on strong push-and-pull as well as the building up of credibility and reliability at the highest management level. The third point is that still relatively little is known on how to manage people effectively in the field of research and innovation. This is, however, no reason to ignore what is already known, but rather all the more reason to concentrate on developing this field of knowledge. In fact, it is expected that this subject will be one of the frontiers of management development for the rest of the century.

EXAMPLE OF TECHNOLOGY TRANSFER

One of the aims of the National Timber Research Institute (NTRI) is to make more efficient use of the South African wood resource as a reliable and economical structural material. The staff of the NTRI are aware of the fact, that to achieve this, two-way communication, or technology transfer, is essential both within the Institute and between the Institute and the forest products industry. Each project is discussed monthly with all interested staff, including the director and division heads. Progress is discussed relative to a research time budget and the planning, including the research time budget, for the next month is discussed. Planning of research application also forms part of the monthly discussions. These sessions can therefore be seen as technology transfer sessions as well as research control sessions. All division heads also meet monthly and each describes briefly what work is currently being carried out in his division. This information is transferred to the staff members and anyone coming into contact with members of the industry is then able to transfer information of a general nature as well as detailed information on his own project.

The Institute also communicates with industry on a more formal basis. The overall research program and budget are approved by an advisory committee that consists of representatives from various official bodies as well as members of the industry. Each project is guided by a steering committee that meets twice to four times a year and is made up of members from those areas of the industry that are actively involved in the work of the particular project as well as representatives of other research bodies and government organizations. Symposia are arranged at which research results are presented and discussed; research reports are published regularly, and a quarterly newsletter is published that deals with various aspects of the research work. An important part of the work of the Institute consists of industry-sponsored development contracts, and in many instances direct assistance has been given in the application of research results in factories and sawmills.

Despite the symposia and numerous articles in popular industrial journals, neither the producers of timber nor the merchants were willing to apply mechanical stress grading, the basis of which was established by the NTRI in 1972. However, the Institute has for many years been in constant touch with the nail-plate industry and as a result of contract work undertaken on their behalf has provided, on a confidential basis, design data for each system. This industry is highly competitive and was desirous of expanding its markets into span ranges that had hitherto been uneconomical with the low stresses assigned to the original visual grades of timber. Thus the truss industry had created a demand for a range of reliable stress grades.

At about the same time that it was establishing the basis for mechanical stress-grading, the NTRI successfully developed a low-cost manually operated stress-grading machine. Members of the nail-plate industry who served on the Stress Grading Steering Committee were aware of this research and its successful culmination and they realized that such machines could be installed by individual truss fabricators to satisfy their own requirements for mechanically stress-graded timber. NTRI staff calibrated the machines and installed them in the factories where they also instructed operators in their correct use.

Thus mechanical stress-grading was launched in South Africa, and the industry exploiting the new opportunities afforded them, expanded rapidly. This resulted in a need for more accurate and more rapid design methods for trusses. To meet this demand, the Institute developed a large and powerful computer program to design nail-plate trusses that was based on a stiffness-matrix plane-frame analysis program developed by an Australian colleague. The accuracy of this program was checked by loading to destruction in the Institute's truss testing rig, a series of 18 trusses with precalibrated members. The program was found to be not only accurate and fast, but also more economical to run than many less sophisticated programs. It is estimated that at present 20% of all roof trusses in South Africa are manufactured from mechanically stress-graded timber.

As a result of the upsurge of interest in mechanical stress grading in South Africa, which was brought to the notice of the members of the Stress Grading Steering Committee, the Department of Forestry, which is also represented on this Committee, made funds available for research into other methods of grading, such as stress-wave-grading, and also to develop a South African machine that would be fully automatic and have a large enough capacity to make it acceptable in a sawmill. The Forestry Council, which allocates industry money obtained on a levy basis to research, is also sponsoring the development of this machine. Such a machine has been designed and is now being developed in collaboration with an industrial firm that specializes in sawmill design and construction. It is expected that, with the current price structure, an extra 20% can be realized from increased yields in the higher grades using this machine.

When the sawmillers became aware of this demand for mechanically stress-graded timber and realized that it was a worthwhile proposition, they imported some large automatic machines. The NTRI evaluated these machines under contract to the suppliers and provided settings for the South African stress-grades. They also assisted the mills with the operation of the machines and solved several problems that arose with the infeed mechanisms. In addition, the Institute set up a discussion group to provide owners of these machines with the opportunity to discuss common problems and matters of mutual interest and to define areas of responsibility to ensure the effective implementation of the grading system that has been achieved.

To ensure the proper control of mechanical stress-grading, the South African Bureau of Standards (SABS), in collaboration with the Institute, has drafted a Code of Practice for the Mechanical Stress Grading of Softwood Timber (Flexural Method), which has been accepted as the basis for mechanical stress-grading in South Africa. The SABS now undertakes to check and calibrate stress-grading machines in the factories and to check their production.

At the same time that the nail-plate industry was realizing the value of mechanical stress-grading, the glulam industry, through personal contact with the Institute and also through the Glulam Steering Committee, became aware of the advantages to be reaped by using mechanically stress-graded timber in the outer laminations of glulam. Using the results of an extensive project on the strength of glulam, the NTRI developed a mathematical model for predicting the characteristic strength (5th percentile strength) of stock glulam beams made with any combination of stiffness-graded laminations. The model takes into account the effect on strength of resawing (deep cutting) stock glulam baulks to produce the popular commercial sizes. In this way the minimum strength requirements set out in SABS 1089: S A Pine Stock Glued Laminated Timber (Stock Glulam) could be met most efficiently and economically. As a result, mechanical stress grading is applied in several plants which manufacture laminated timber products such as container floors.

Parallel to the developments in mechanical stress grading, the NTRI was involved in a national experiment to provide data for the establishment of a visual stress-grading system with grades matching and mechanical stress grades. This was developed under the broad control of the Stress-Grading Steering Committee, but specifically by a specially constituted *ad hoc* project committee and through liaison with the SABS.

Thus the transfer of the technology by which stress-grading has been introduced to make some effective use of South African structural timber has been effected over a number of years using a variety of means of communication on technology transfer at different levels of the industry—with the policy-makers on advisory committees, with mill personnel in factories, with technical personnel on steering committees, and with discussion groups.

As the transfer of stress-grading technology proceeded from research to adoption by the industry, problems arose at each stage, and each of these had to be solved in a different way. The purposeful coordination of the transfer of this technology by the NTRI who developed it, and proper communication at each stage with all the groups which were involved, resulted in its successful application.

REFERENCES

BOSMAN, D. L. 1969. Research and development—a prerequisite for economic progress in industry. EASA 26:(6)140–145, November/December 1979. CSIR Ref. No. RU 1.65.

———. 1973. Principles and practice of R & D management. HOUT 68. Timber Research Unit, CSIR. Paper presented at the IUFRO Division 5 meeting, South Africa, 1973.

———. 1977. Research workers: Produce or perish. Wood Fiber, 8(4):262–266. CSIR Ref. No. R.HOUT 91.

BRIGHT, JAMES R. 1971. Turning research and development into a national resource. Proceedings of a Symposium on Research and Development—a programme for economic progress. Jan Smuts, 1 October 1971. 433 pp.

———. 1972. A brief introduction to technological forecasting. The Pennaquid Press.

CHARPIE, R. A. 1970. *Technological innovation and the international economy.* Paper delivered at a Science of Science Foundation Symposium on Technological Innovation and the Growth of the Economy. Cambridge. Wiley-Interscience.

DAILEY, C. A. 1967. Entrepreneurial management. McGraw-Hill, New York.

DRUCKER, PETER F. 1969. The age of discontinuity. Heineman, London.

GARTNER, J, AND C. S. NAIMAN. 1976. Overcoming the barriers to technology transfer. Research Management, 22–28.

HOLT, K. 1978. Information inputs to new product planning and development. Research Policy 7:342–360.

LEVITT, T. 1968. Innovation and marketing. Pan Books, London.

LOUBSER, R. S., AND F. J. H. LE RICHE. 1979. Die benutting van navorsingsresultate (The utilization of research results.) Paper delivered at the Annual Meeting of the South African Academy of Science and Art on 21 June 1979, Stellenbosch, South Africa.

ÔZDAS, M. N. 1979. Opening address. Published proceedings of the International Conference on Technology Transfer in Industrialized Countries, Estoril, Portugal, November 1977. Sũthoff and Noordhoff International Publishers BV, Alphen van den Rijn, The Netherlands.

PRESIDENT'S MESSAGE TO CONGRESS ON SCIENCE AND TECHNOLOGY. Weekly compilation of Presidential Documents, 8(12), March 1972.

PROCEEDINGS OF THE SYMPOSIUM ON TECHNOLOGY TRANSFER, PRETORIA, 1974. Organized by the Council for Scientific and Industrial Research and the Engineers' Association of South Africa.

TEECE, D. 1976. The multinational comparative and the resource cast of international technology transfer. Cambridge, MA.

TWISS, B. C. 1974. Managing technological innovation. Longman, London and New York.

U.S. DEPARTMENT OF COMMERCE. 1974. Technology transfer and utilization recommendations for redirecting the emphasis and correcting the imbalance. National Academy of Engineering, National Technical Information Service.