

The role of a research and development institute in the development and diffusion of technology

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WORKING PAPERS



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**“The Role of a Research and Development Institute in the Development
and Diffusion of Technology”**

by

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1. Introduction

In the context of late industrialisation the effective transfer and adaptation of technology is of great importance for economic development. International technology transfer is not a costless process, but requires considerable technological effort and investments in the development of technological capabilities.

Ever since the Arusha declaration in 1967, the Tanzanian government considered a weak technological research and development base as one of the reasons for slow growth of the manufacturing sector (Kahama 1982). To tackle this problem an aim of government policy was to set up centres of excellence in research and development.

One of these institutes was the Tanzanian Industrial Research and Development Organisation (TIRDO), which started operations in 1979. The basic functions of this organisation are to carry out applied research, to provide technical services to industry and to manage a system of documentation and information designed to enhance industrial production. An important task of TIRDO is to adapt technology to local circumstances and to transfer it to domestic industrial firms. The technology projects of the institute make use of domestic resources and try to substitute for imported products.

The aim of this article is to take TIRDO as a case study of technology development and technology diffusion in the context of an African developing economy. On the basis of an in depth analysis of a large number of technology projects, the article tries to identify the factors contributing to or hampering the successful development and diffusion of technologies in the context of a developing economy.¹

2. Theoretical Background

The theoretical rationale for funding public research and development organisations is market failure. Given the semi-public nature and positive external effects of research and development, the volume of private investment in R&D will tend to be suboptimal. In the context of a low income economy, this is compounded by imperfect information, lack of skilled personnel and financial resources in the private sector. This paper examines whether a public research and development institute can fulfil its theoretically defined functions, through successful development and diffusion of appropriate technologies.

In this section, we present a simplified scheme of the technology development process to structure the empirical analysis of technology development projects in section 4. The scheme involves two basic assumptions. The first is that a research and development institute in a low income economy will not develop technology from scratch, but rather will use and adapt existing technology to fulfil technological needs: it innovates rather than invents², it focuses more on

¹ This paper is based on the MSc. thesis of B. Bongenaar, *Analysing Technology Development*, Eindhoven, March 1997. This thesis was based on 8 months of fieldwork at TIRDO. We thank TIRDO and its former director Dr. G. Njau for the opportunity to execute this research project. We should like to note the impressive degree of openness on the part of the staff of TIRDO, to outside examination of their projects. The aim of this paper is not to offer easy criticism by uninvolved outsiders, but contribute to the understanding of the factors which may contribute to or hamper the success of technology development. Earlier versions of this paper were presented at the conference on The Industrial Performance of Tanzania, Eindhoven, June 1998 and the EADI seminar on Innovation in the third world, The Hague, September 1998. We thank Leon Oerlemans and Henny Romijn for useful comments.

² Invention is the output and the process by which a new idea is discovered or created. An innovation is an idea or object perceived as new by a group (Rogers, 1983).

specific techniques than on wider technologies.³ The second assumption, based on the charter of TIRDO, is that the target group of the research and development organisation consists of domestic industrial enterprises.

Figure 1: Phases in the Technology Development Process

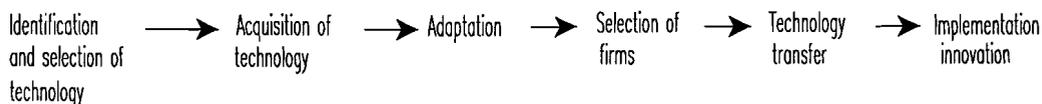


Figure 1 presents the six main phases in a model of the technology development, seen from the perspective of an R&D institute: identification and selection of technologies, acquisition of technology, adaptation, selection of firms, technology transfer to firms, and implementation of innovations. These steps have to be executed for each technology development project and will be analysed separately.

The phases are analytical rather than purely sequential. In one sense, the phases do represent a logical sequence in time. Identification precedes acquisition and acquisition precedes adaptation. In a similar fashion, selection of firms precedes transfer of technology and transfer precedes implementation. However, the selection of firms, may precede identification of technology and technology transfer and implementation involves further adaptation. Also there are relationships of circular causation from “later” phases, to “earlier phases” (feedback) and from earlier to later phases and activities in different phases can - and often should - be undertaken simultaneously. Therefore the scheme should be primarily seen as an analytical device, rather than a full-blown theoretical model.

This paper examines the innovation process from the perspective of the research institution. Thus, we examine the transfer of technology from the R&D institute to industrial organisations. From the perspective of the receiving organisations and from the perspective of innovation theory, the focus is on the adoption of innovations by firms and organisations. In this study we do not study the determinants of innovative behaviour by organisations or of their adoption decisions. We only examine the ways in which an R&D institution can try to influence firms’ adoption decisions, and the effectiveness of such efforts.

It should be stressed that R&D is only one aspect of a more complex model of technological change and innovation presented by Kline and Rosenberg (Malecki, 1991, pp. 114-117). In that model the interactions between R&D, technology and markets are very important, as the market ultimately defines the technology needs and specifications and is the customer for R&D outputs. Technological change only occurs if these different aspects are well co-ordinated. The present analysis concentrates on the functioning of a R&D organisation and tries to fill part the black box of ‘research’ in the Kline and Rosenberg model of technological change. The aims are practical rather than theoretical: identifying strengths and weaknesses in different phases of the process of technology development.

³ There is much refined discussion of concepts and definitions in the literature, which we will try to avoid in this paper. Technique generally refers to the total of means and procedures for the production and marketing of an existing good. Technology is the wider frame of reference (knowledge, ways and means) within which techniques can be applied to a set of objectives (van Egmond, 1993, pp. 15-16). However, the difference between the two concepts is a matter of degree. In this paper, we will use the term technology in a rather rough sense, referring both to specific techniques and the knowledge required to make these specific techniques work. Where the wider concept of technology is referred to, this will be clear from the context.

2.1 Identification and Selection of Technology

The success of the technology development process ultimately depends on the extent of successful transfer to and implementation of technologies by firms in the target group. Selection of technologies by the R&D institute should proceed with this goal in mind. As resources are limited (especially in developing countries), the R&D institute should select technologies under investigation with great care. The two main concepts in the identification and selection phase are: *assessment of needs* and *appropriateness*.

In order for a technology to be adopted by the institute's target group, there has to be a need for it. For a research and development institute the target group or market consists of domestic industrial firms and their needs. These needs, in turn, are based on the needs of the customers of the target group: consumers and other industries (UNIDO, 1991, p. 167).

It is not totally undisputed that needs should be used as a criterion for selection decisions. According to Rogers (1983, p. 166): "Innovation can lead to needs as well as vice versa". But given the uncertainty of future developments, the adoption rates for technology push innovations will tend to be lower. Therefore, a R&D institute should let firms define their own needs. Firms, in turn, will base their needs upon their perceptions of existing or potential needs of their customers.

If information about needs is a necessary condition for innovation, a technology development institute should assess the needs of industry at an early stage in the technology development process. To assess the needs of larger groups of enterprises, the organisation can make use of formal needs assessments or informal needs assessments. The *formal needs assessment* consists of an initiative of the development institute to analyse the market need for a type of technology. A drawback of this approach is that it requires substantial investments in market research by the institute, for this sole purpose.

Informal needs assessment refers to the assessment of technology needs through regular contacts with the firms of an industry. The industry provides the product market knowledge that is the basis for assessing technology needs. In such an innovation network, a situation can be created in which all actors involved benefit from the network. The quality of an informal needs assessment depends on the frequency and intensity of contacts and the size of the network (Wissema and Euser, 1988, p. 19-29). A clear advantage of such an approach is that it also makes contributions to several other phases of the technology development process. The main disadvantage is that it requires constant networking efforts and costs on the part of the research organisation and other participants in the network.

A second important criterion for technology selection by an R&D institute is the appropriateness of the technology. *Appropriateness* refers to the evaluation of effects of technologies within the wider societal context, both in the short run and the long run (Riedijk, 1987, p. VIII). The chosen technology should be appropriate in terms of local market conditions, local resources, labour supply and quality of work force, environmental and geographic conditions, cultural features and national objectives and policies (Van Egmond, 1995, p. 10, 1993, p. 56, UNIDO, 1991, p. 167) The chosen technology should be appropriate both from the perspective of the welfare of the people directly involved and socially appropriate from the perspective of collective welfare.

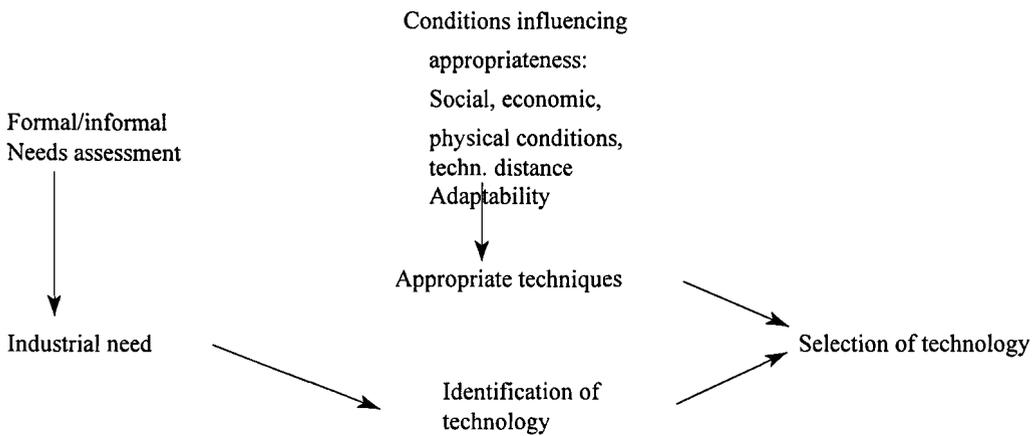
An other aspect frequently mentioned in the context of appropriateness is *technological distance*. This is defined as the technological sensitivity to differences in pertinent social, economic and physical circumstances. Westphal (1993, p. 5-6) links the technological distance to the wider concept of the technological capabilities of a country. The greater the technological distance, the more difficult the transfer of technology becomes (see also Caniels, 1999). A wide gap between the technological capabilities of a country and the characteristics of a given technology increases the technological distance and has a negative impact on the possibilities for successful technology transfer by the R&D institute (Van der Straaten et al., 1992).

A further variable affecting the appropriateness of a technology is *adaptability*. Adaptability refers to the question whether the research and development organisation has the capabilities to engage in a given technology development process. Mourik, Ouderaa and Hage (Mourik et al., 1991) describe the assessment of adaptability as a basic decision to be made by the management

of a R&D institute. In the process of technology selection, criteria such as financial risks, technical risks, the levels of investment required and the availability of the necessary capabilities and know how have to be assessed from the perspective of the research and development organisation itself.

Figure 2 summarises the relationships between the concepts discussed above. The first step in the selection of technology is the formal or informal identification of needs. In this step a technology is selected that is directly linked to a specific project. This project is linked with the needs of an industry.⁴ In the second phase, the selection process focuses on the most appropriate techniques within a wider technological framework.⁵ The concept of appropriateness tries to cover all the above mentioned aspects: social, economic and physical appropriateness, technical distance and adaptability by the research and development organisation. As mentioned the appropriateness refers to the desirability of the technology for solving certain problems and its suitability to physical, social, economic and technical aspects of the industrial environment. The second aspect refers to the time required, the resources and capabilities needed for the acquisition, adaptation, diffusion and implementation of the technology as compared with the capabilities (financial, knowledge, equipment) of the R & D organisation.

Figure 2: Identification and selection of techniques



2.2 Acquisition of Technology

Technology development as analysed in this paper involves the adaptation of already existing technologies. This implies that the technology needs to be acquired before the adaptive activities of the R&D organisation can commence. The technology will normally be found on the international technology market, a market characterised by extreme imperfectness and a weak and dependent position of developing countries (Egmond 1993, p. 86).⁶ The R&D institute has

⁴ At this stage the selection of the project is the main issue. Thus, the caustic soda project at TIRDO aims at producing caustic soda. The specific way of producing this commodity is secondary.

⁵ In figure 2 we do not make a precise distinction between selection of technology and selection of techniques, in order not to complicate the figure too much. The reason for this is that in the subsequent steps of the analysis the acquisition and transfer of the techniques, involves not only the techniques themselves, but the know how and understanding required to operate them (see also footnote 3).

⁶ TIRDO projects do not involve the acquisition of domestic technologies.

to try to acquire the coveted technology in an imperfect market at the most favourable conditions.

The cost of technology depends on the manner and the package in which it is transferred. There are two kinds of costs: (UNCTAD 1972, p. 24-27): *direct costs* associated with the purchase, development and use of a technology and *indirect* hidden costs associated with restrictions on the use of the technology. ESCAP (Egmond 1993, p. 81-84) distinguishes five categories of *technology flows*:

Free-flow of technology: Technology is normally embodied in information, suppliers are publicly accessible, the direct costs of transfer are low, indirect costs are negligible.

However, free flow requires the greatest effort in mastering the technology.

Technology flows through the purchase of products: Products can be a source of embodied technology, and can be accompanied by reference materials. This type of technology flow plays an important role in international technology transfers (ITT), but it is very difficult to measure due to its informal character. Direct and indirect costs are relatively low.

Sponsored flows: Third parties (e.g. international agents, local governments) pay the costs of the technology transfer. Occasionally the indirect costs will be paid by the recipient.

Flows embedded in commercial contracts: Technology flows take place as a byproduct of commercial contracts between parties. Among others, the commercial contracts can refer to plant construction, consultancy, management contracts, subcontracting. As technology is not the explicit focus of the contract, the direct costs, but especially indirect costs can be high.

Flows through commercial technology acquisition contracts: This is a pure form of technology transfer, based upon an agreement for the specific technology. Direct costs are high.

Central to the choice between flow mechanisms is the concept of *unpacking*. Unpacking involves the knocking-down of the technology into its components, and the separate purchase of every component, where possible from different suppliers (Egmond 1995, p. 20). The R&D organisation will have a stronger bargaining position, if it can unpack a technology (UNCTAD 1978, p. 11-13). It has more choice with regard to the channel through which the technology will be acquired (Egmond 1993, p. 104-114). An unpacked technology can be acquired through simple direct transactions, with free price setting. Other advantages of the unpacking strategy are the increase of opportunities to build up technological capabilities, more control over the technology transfer, and the decrease of technological dependence on the suppliers of technology.

The efforts needed for an unpacking strategy in technology acquisition usually are higher, as the whole process of unpacking and reconstruction is very time consuming. The total costs, however, usually are lower (UNCTAD 1978, p. 33).

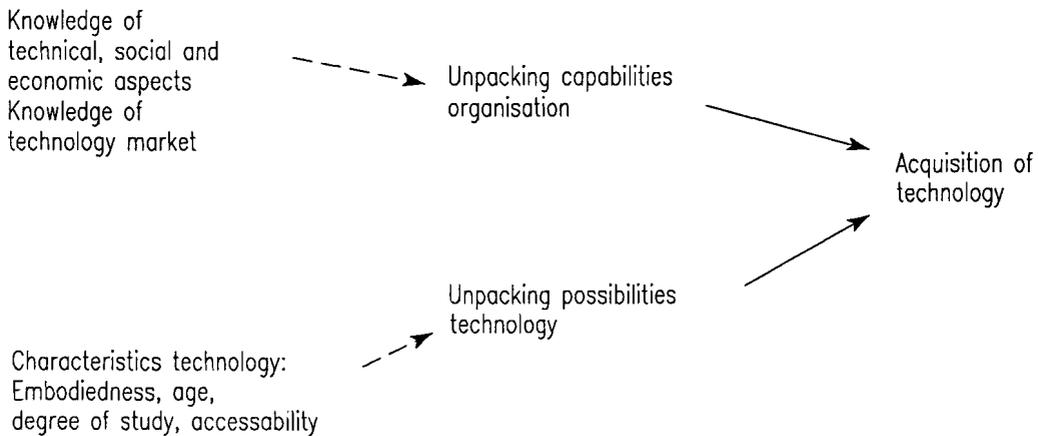
Unpacking is not a simple strategy. The degree of unpacking in technology acquisition depends on unpacking capabilities of the R&D institute and the unpackability of the technology involved. *Unpacking capabilities* involve the capability to understand, divide and combine the technology. Furthermore, an unpacking strategy requires sufficient knowledge of the technology market to source the different elements from suppliers, and the ability to pick the transfer mechanism that is most advantageous, based upon (socio-economic and financial) criteria of interest (UNCTAD 1978, p. 33).

Unpackability depends not only on the organisation's capabilities but on the *unpacking possibilities* of the technology. The unpackability of a technology is determined by a set of characteristics including age, embodiedness of technology, accessibility, freedom of transfer and the extent to which technology has been studied. The international technology market does not always allow for the unpacking of a technology. Especially with new technologies, or technologies that concern core elements of the suppliers' industrial sector, it may be impossible to use an unpacking strategy (Van Egmond, 1995, p. 20). Old, widely studied, publicly available technologies, not embodied in expert knowledge are most suitable for an unpacking strategy.

The direct outcomes of the technology acquisition process include: the costs of a technology, the type of technology transfer deal and the type of flow channel used. The most favourable outcome should result in low direct and hidden costs, direct technology transfer transactions

without conditions attached, through public or sponsored channels. The relevant relationships are summarised in figure 3.

Figure 3: Acquisition of Technology



2.3 Adaptation

The purpose of adaptation is to make a technology more appropriate to local conditions. The adaptation phase is an extremely important phase in the transfer of technology to developing economies (Van Straaten et al. 1992; Dar 1990, p. 137-137). Many innovations fail due to inadequate attention to differences in the socio-economic and physical conditions in the originating and target environments.

The degree of care in selecting appropriate technologies in the selection and acquisition phases affects the degrees of adaptation required. The more effort is put into the selection of an appropriate technology, the less effort will be needed in the adaptation phase. But even very carefully selected and acquired technologies will never be appropriate in every respect. They are always in need of further adaptation.

A technology is developed in a specific society, under specific conditions and for specific goals. The technology must be redesigned when the circumstances alter, which normally is case with international technology transfer. Other things being equal, an unpacking strategy in the acquisition phase calls for greater efforts in the adaptation phase. Besides the implementation of changes resulting from differences in local circumstances, the different unpacked elements have to be recombined.

The basic goal of the adaptation process is to compensate for the differences between environmental conditions before and after the technology transfer. Therefore, the adaptation process depends on the *characteristics of the origination environment* embodied in the design of the technology and the *characteristics of the target environment* in which the technology has to function. The differences between the circumstances in which the technology has originally been designed to function, and those in which the technology will have to function, define the setting and need for adaptations.

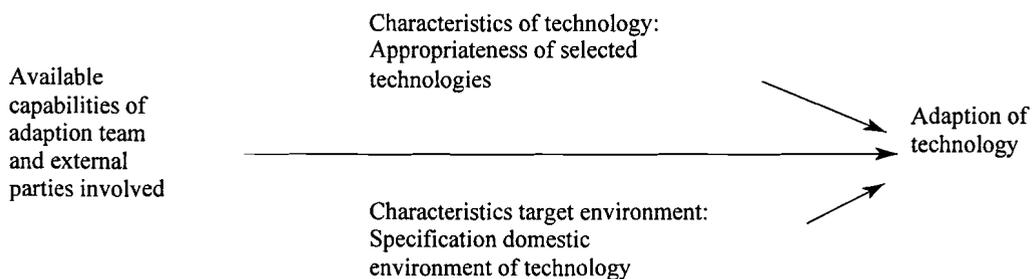
The adaptation of a technology not only requires the adaptation of knowledge to local factor conditions, but also the capability to modify and add products and processes to suit local preferences and requirements. Adaptation also involves measures to speed up absorption of a

technology, by making it more appropriate for local use, and specifying required methods for introduction (e.g. training) (UNIDO 1991, p. 177).

In the adaptation phase, the participating technical staff is the main input. However, staff members cannot operate without non technical capabilities within the team. Market knowledge, process control knowledge and knowledge of the social and economic implications of the technology also are essential for successful adaptation of technology (Mourik et al., p. 111-112). Therefore the *characteristics of the adaptation team* and its external partners are of considerable importance. The capabilities involved in the adaptation process are very important. They influence the process in two respects. First, they provide the knowledge for the identification of the target and originating environmental conditions.⁷ Second, they provide the knowledge needed for implementation of the adaptations.⁸

Figure 4 represents this phase in the technology development process. This figure includes three variables: the characteristics of the target environment, appropriateness of the acquired technology to the target environment⁹ and the capabilities of the adaptation team and the external parties involved in the adaptation process.

Figure 4: Adaptation



2.4 Selection of Firms

The problem with the selection of firms for transfer of adapted technologies is, that the decision of the R&D institute to transfer an innovation to a firm must simultaneously be accompanied by a firm's decision to adopt an innovation. The interest of the R&D institute lies in successful transfers to firms of technologies developed at the institute. Therefore, it should select firms from the perspective of achieving the highest possible success rate in the transfer of the adapted technology. The selection process also involves the process of getting firms interested in an innovation and persuading some of them to consider adopting it.

If the selection of technology has been done competently, the link between the offered technology and the interested firms is provided by the need for such a technology. The model of technological development of Kline and Rosenberg (see Malecki 1991, p. 114-117) postulates a direct relationship between the market for technology and the technological development actions of innovation institutes. If the relationship is too weak, it can diminish the chances of

⁷ This also is one of the main reasons for the need for cooperation of the target group and non technical members in the adaptation phase.

⁸ By means of changing elements of the technology or by appending new elements.

⁹ Originally, the model included the specification of the original environment of the technology as a variable. However, often no specific environment of origin could be identified and sometimes different parts of a technology had different origins. Therefore the final model for this phase uses the appropriateness to characterise the technology, rather than its environment of origin.

successfully transferring the technology developed by the organisation to the firms in the technology market.¹⁰

Most industrial firms do not make innovation decisions easily. Firms need to be supported in making their innovation decisions. In a model of innovation decisions, Rogers (1983, p. 163-172) identifies two phases which determine the innovation decisions of firms: the *knowledge phase* and the *persuasion phase*. In the knowledge phase, a decision making unit (DMU) is exposed to the existence of the innovation and gains some understanding of how it functions. In the persuasion phase, the DMU develops a favourable or unfavourable attitude towards the innovation, based upon the information available to it. The acquisition of knowledge in the knowledge phase is influenced by the characteristics of the firms in question. Decision making in the persuasion phase is influenced by perceived characteristics of the innovation.

To influence these processes, various *communication instruments* can be used. In the knowledge phase, the communication channels should focus on characteristics of the DMU, its innovativeness and its communication behaviour. During the persuasion phase the DMU's perceptions of the characteristics of the innovation can be influenced in order to create more positive attitudes towards the innovation.

Several instruments can influence the innovation awareness and the innovation decisions of firms. Communication is crucial to the creation of awareness of innovative possibilities at firm level. (Wissema and Euser, 1988, p. 75-80). Within an innovation network, informal communication with opinion leaders can create more awareness of the innovation, and stimulate the acceptance of the innovation. Another channel of communication makes use of change agents, who can take the potential adopters' point of view and help them with their innovation decisions (Rogers 1983, p. 318). The R&D institute can also focus specifically on innovative firms, which are prone to adopt an innovation at an early stage. In the persuasion phase, the R&D institute can make use of financial and non-financial incentives and it can approach gatekeepers. Gatekeepers are key figures within a firm, who have frequent (in- and external) informal contacts, are interested in new developments and are recognised as such by other members of the organisation. They can serve as bridge between the R&D institute and the firm for the diffusion of knowledge. In general, the more effort is invested in supporting firms in their innovation decisions, the greater the number of firms available for selection.

Pack (1987) emphasises that the successful functioning of a technology within a firm depends on the firm's ability to incorporate the technology in its organisation. The selection of firms should thus depend on the R&D institution's assessments of the technological, organisational, information processing, managerial and educational capabilities necessary to incorporate a new technology into the organisation (see also Laseur, 1989, 1991).

Factors affecting the success of technology transfer include the relative importance of hardware, human skills and information, the possibilities of substitution between them, the organisational requirements of the technology and the nature of co-operation between transferee and transferor. The selection of firms should be based on a minimisation of discrepancies between the characteristics of the technology and the technological and organisational capabilities of the firm. The better the match between the capabilities of the firm and the requirements of the technology, the greater the chances of successful transfer in the next phase.

The sub model for the selection phase is presented in figure 5. It combines the actual selection of firms for technology transfer with the heightening of innovation awareness of firms, and persuading firms of the advantages of innovation.¹¹

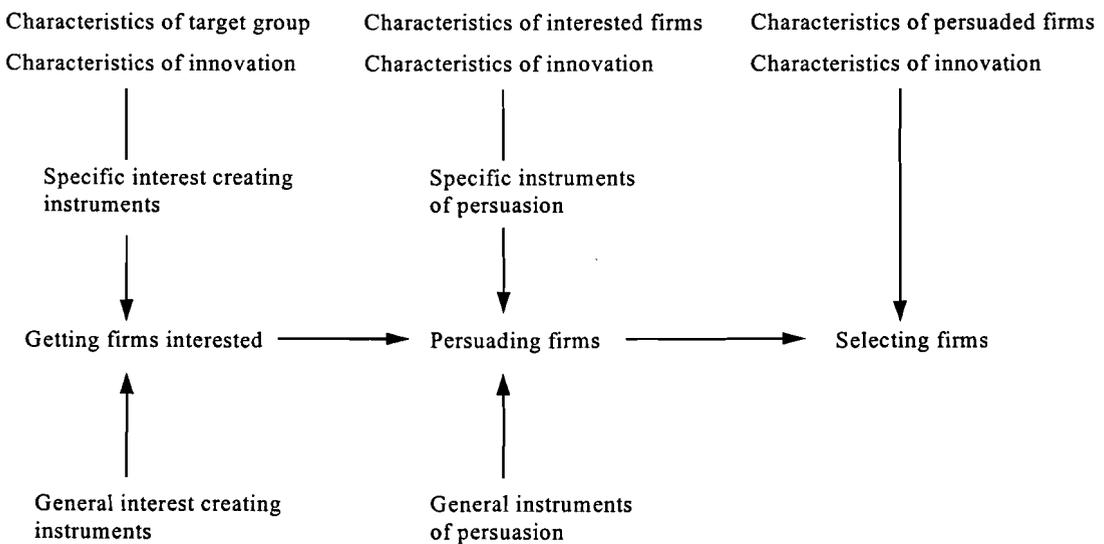
¹⁰ If the relationship is too strong, it can limit the freedom of a R&D organisation to select both technologies and firms.

¹¹ It is clear that creating interest and persuading firms overlaps with the first phase of identification and selection of technology, in which the needs of the target group are identified. Although, raising interest /and awareness is discussed here in the context of the selection phase, this activity can be undertaken throughout the whole technology development cycle. It is even preferable to undertake these activities at early stages in the cycle.

Figure 5 integrates a number of elements from the theoretical discussion above. At the left hand side of the figure, one sees the use of instruments which heighten firms' awareness of the possibilities of innovation and get them interested in an innovation. The instruments include communication methods, networking and the use of change agents. A distinction is made between general instruments which draw the attention of firms to the need for innovation and the potential role of the research and development institute and specific communication instruments tailored to the characteristics of the innovation and the characteristics of the firms in the target group.

In the middle of the figure, one finds instruments of persuasion, such as incentives for firms and approaching gate keepers. To persuade the interested firms to engage in innovation, the R&D organisation should play an active role. Again a distinction is made between general instruments and specific instruments. Specific instruments aim at persuading or convincing one or more promising firms to adopt the technology.

Figure 5: Selection of Firms



At the right hand side of the figure, one finds the actual selection of firms to which a technology will be transferred. From the perspective of the firm, the transfer of the technology is an innovation. The aim of the selection process is to select the firms offering the greatest chances of success in the diffusion of the new technologies. The selection decision depends on assessments of the capabilities of the interested firms in relation to the characteristics of the innovations. A specific technology will require specific capabilities within its direct environment. Firms that already have many of the required capabilities will need less capability building for successful innovation. Consequently, these firms will offer better opportunities for a successful transfer of the innovation in question.

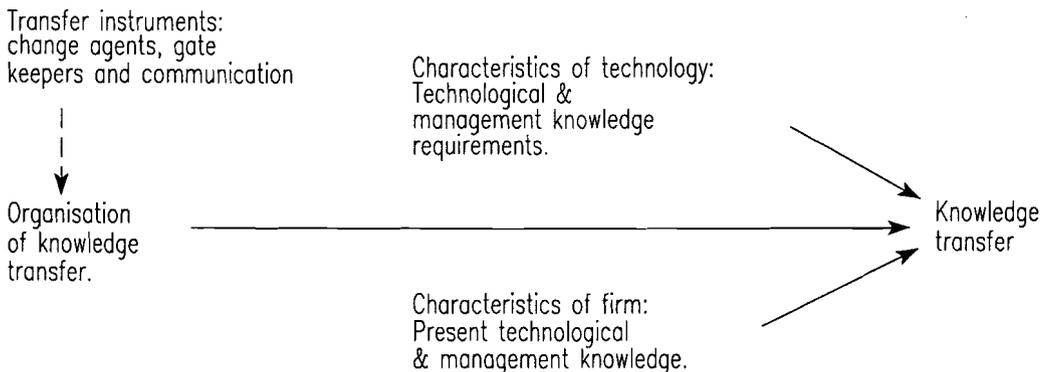
2.5 Technology and Knowledge Transfer

During the technology transfer phase, the technology must be transferred to the selected firms, which have decided to adopt it. The transfer of hardware consists of a simple transaction of machinery and goods. Written information (infoware) needs time to be understood, but in itself it is easy to transfer. Due to the often tacit and uncoded nature of technological knowledge, special attention has to be paid to the transfer of knowledge via training, instruction, learning and education. The transfer of human knowledge (human ware) involves longer learning periods, and is essential to the functioning of the technology (Laseur 1989, p. 82-83). The difference between existing knowledge capabilities and the knowledge requirements of the technology, determines the required time and effort for the transfer process.

Wissema and Euser (1989, p. 76-80) define instruments for the organisation of knowledge transfer. They write that good organisation of the process will accelerate the diffusion process. The first instrument is the use of the right communication attributes. Open, and bi-directional communication stimulates the mutual understanding. Secondly, they emphasize the functions of change agents in this phase. The change agent can assess problems at an early stage, and can take necessary action to correct them in time. The third instrument focuses on the function of gatekeepers. They can stimulate the adoption from within the organisation, and function as a knowledge bank for other members of the firm during the adoption process.

A full model of technology transfer should include all aspects of technology. However, the transfer of knowledge requires most time and effort. Therefore, figure 6 represents the knowledge transfer aspects of technology transfer. Two aspects are important in this model: the knowledge gap and the organisation of the knowledge transfer. The knowledge gap is determined by discrepancies between the knowledge required for the innovation, and the existing knowledge within the firm. A small knowledge gap simplifies the transfer process. The organisation of the transfer refers to the instruments used: communication instruments, change agents and gatekeepers.

Figure 6: Technology and Knowledge Transfer



2.6 Implementation and Diffusion

In the implementation phase, special attention must be paid to problems arising during the implementation of the innovation and its diffusion to managers, engineers and production workers within the organisation. In this phase the tacit knowledge necessary to make a technology function in a given environment has to have a chance to develop.

Change agents may play a positive role in this phase. The knowledge and technology transferred, has to be effectively diffused throughout the organisation and built into a functional system. New problems will arise in the course of the introduction of the innovation. Wissema and Euser (1988, p. 55) distinguish internal and external problems. Internal problems have to do with resistance to change and occur when a new technology is introduced into the various activities of a firm. This resistance to change is mostly due to a lack of knowledge about the

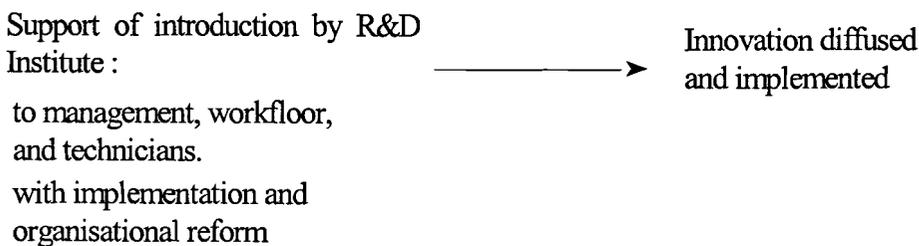
usefulness and functions of the innovation at lower levels in the organisation. It is caused by incomprehension rather than unwillingness. External problems arise from a changing environment and can hamper the introduction of the innovation. Both problems can be reduced through close guidance of the implementation process.

During the implementation of an innovation, further adaptation or re-invention may be necessary. Rogers uses the term re-invention to describe the phenomenon that an innovation has to undergo changes in design in the introduction phase (Rogers 1983, p. 16-17). Such re-invention may be necessary even when adaptation processes have been effective. But the more flawed the process of adaptation, the greater the likelihood of reinvention. The process of re-invention needs support from outside, since it is not likely that firms have sufficient knowledge and experience concerning design activities. Dar (Dar 1990, p. 140) writes that re-inventions are inevitable, because no two firms or organisations are identical. Therefore, support for the implementation of new technologies should always be available.

Another important aspect of implementation has to do with organisational change (Dar includes changes in management in the concept of re-invention). The organisation structure has to be aligned with the production system in which the technology functions (Laseur 1989, p. 39). Only when the firm develops sufficient technical and management capabilities, can an efficient system of production develop, and can the firm enter into a continuous process of technology adaptation and improvement in the future (Westphal and Evenson, 1993). Thus, the implementation and introduction of new technologies need to be actively supported both from within and from outside the organisation. A long term involvement of engineers from the R&D institute and activities such as regular meetings and training sessions, may also provide the necessary support for firms in the implementation phase.

Figure 7 summarises the factors involved in implementation. A successful implementation of an innovation has the following characteristics: the knowledge concerning the innovation should be diffused to all people involved, the innovation should be operative, and the expectations of both the firm and the R&D institute should be realised. The stronger the support of the R&D institute for the introduction of a new technology, the greater the chance of successful implementation.

Figure 7: Implementation and Diffusion



3. The Research and Development Environment

R&D in Tanzania is mainly conducted within government organisations. R&D in firms is almost non-existent. Ever since the Arusha declaration in 1967, the Tanzanian government has emphasized the need for an increasing share of manufacturing in national income. A weak technological research and development base was seen as one of the reasons for slow growth of the manufacturing sector (Kahama 1982, p. 8/9). To tackle this problem, the government aimed at creating 'centres of excellence' in research development. However, Government spending on R&D is modest. Since 1986, the share of R&D in expenditures has been declining, though policy statements called for increased efforts. In 1988/89, the share of R&D expenditures in total expenditures was 1% of government expenditures, against 1.1% in 1978 (Mlawa and Sheya, 1990, table 3.4).

As a result, R&D institutes did not receive sufficient funding for their activities and many institutes have had to scale down their activities. Usually, budgets were sufficient only for operational expenses such as wages. Hardly any funding was available for the R&D activities themselves. Some institutes succeeded in getting some form of external support or generated funds by offering consultancy, training and technical services to enterprises. Usually, the income thus generated is modest (Mlawa and Sheya, 1990, p. 14-17).¹²

Eight institutes are primarily involved in industrial research, development and design. The organisations have similar or partly similar goals. Four of them have goals that overlap with those of TIRDO: the Tanzania Automotive Technology Centre (TACT), the Tanzanian Engineering and the Mechanical Design Organisation (TEMDO), the Centre for Agricultural Mechanisation and Rural Technology (CAMERTEC) and the Institute for Production Innovation (IPI).

The Tanzania Industrial Research and Development Organisation (TIRDO) started its operations on April 1, 1979. The basic functions of the organisation were to carry out applied research, to provide technical services to industry and to manage a system of documentation and information designed to enhance industrial production.

From the very beginning, one of the main problems was the lack of sufficient funds to attract engineers and acquire equipment. UNIDO advised that funds should be made available for a rapid expansion of TIRDO. With funding from the UNDP, the EEC and the World Bank laboratories and facilities were created between 1980 and 1990, but not all planned facilities have been realised. In constant 1987 Tanzanian Shillings, total funding increased from 66 million shillings in 1980 to 233 million shillings in 1990; in the same period public funding increased from 66 million shillings to 120 million shillings. After 1990, public funding and the development of the organisation stagnated. Total receipts continued to rise, among others due to increased efforts in services and consultancy. Expenditures increased even more rapidly resulting in increasing deficits (Chambua, 1990; TIRDO accounts, deflators from World Bank, stars data bank).

The organisation structure of TIRDO consists of five layers. At the top, the council is mainly responsible for the supervision of the organisation on behalf of the government. The Director of Research and Development is responsible for the actual technical output of the organisation. Three departments provide the services of the organisation and execute the R&D projects:

- the industrial technology department. The main tasks of the department are the analysis of chemical samples, chemical engineering, food technology, processing activities and cleaner production consultancy.
- the engineering department. Its main tasks are mechanical engineering in projects, mechanical engineering services, electrical instrumentation repair and energy services.
- the information department. Its tasks are providing internal library services, information services to industry, publication of TIRDO documents and the execution of extension services.

The aim of TIRDO is to promote the manufacturing of industrial goods and to stimulate the use of local resources. Potential clients include both small and medium scale and large scale enterprises. According to its statutes, TIRDO's activities include: the training of technical personnel, development and adaptation of technologies, servicing domestic industries, monitoring technological developments, co-ordinating the execution of R&D and the promotion of new technologies. Due to insufficient resources, and an overlap in goals with other organisations in Tanzania, TIRDO's activities are more limited in practice. They focus on (TIRDO 1993b, p. 2):

- Consultancy studies for industry. The carrying out of feasibility studies for its own and other products to analyse economic viability of new products or processes.

¹² Income from services in the R&D sector estimated at 15% of total income, external assistance at 30% of total income.

- Execution of technical (R&D) projects. The execution of technical development projects and showing the technical viability of the adapted processes or products.
- Information supply to industry. Supplying specific technical information to industry.
- Technical services for industry. Offering analytical service, repair and maintenance of instruments and equipment (electronic and mechanical), welding services, material testing services and energy auditing.

The budget of TIRDO comes from: treasury funding; project capital grants, payments for services to entrepreneurs and other income from rents and sales of products.

The growth of the budget has not been always sufficient to compensate for annual inflation. Especially in the first few years of operation, and at the beginning of the nineties, the growth of nominal budgets did not keep up with inflation. The relative importance of the income categories: payments for services and other income in total income have been increasing rapidly, from 35% in 1989 to 60% in 1994.

In 1995 TIRDO employed 128 staff members of which 26 university graduates. Educational levels are represented in table 1.

**Table 1:
Educational Levels of TIRDO Staff in 1995**

<i>Department</i>	<i>High</i>	<i>High middle</i>	<i>Low middle</i>	<i>Low</i>	<i>Unknown</i>	<i>Total</i>
Industrial technology department	11	5	4	6		26
Engineering department	7	5	7	4		20
Information department	2		3	3		8
DG / DRD / DAF office	3	2	2	3		10
Administration		3	5	23	1	32
Accounts	1	2	1		2	6
Estates			5	9		14
Dispensary		2	2	2		6
Total	26	19	29	51	3	128

Source: Staff List TIRDO 1/10/95,

Notes: High: University, Low/Middle: form III and above, Low: below form III or no education

4. The Field Research

Between 1979 and 1996, twenty five technology development projects were executed by TIRDO (see Bongenaar, 1997, Appendix C)., Using the analytical framework discussed in section 2, twelve of these projects were examined in this study. The unit of measurement is the project. On the basis of the analysis of the projects, we derive conclusions about the unit of analysis, the Research Institute.

The first author of this paper spent eight months at TIRDO. Two projects - national dyes and caustic soda - were investigated in great detail. Research methods included repeated open interviews with project officers and document research. Another ten projects were examined with help of a standardised questionnaire completed by the project leaders, again supplemented by documentary research. (For more detailed discussion of the technical aspects of the projects, their output and the research findings, see Bongenaar, 1997). With the exception of three projects (castor oil, satellite receivers and turkey oil), all projects were well documented. The twelve projects are briefly described in section 4.1. In the subsequent sections, we discuss the

different analytical phases of technology development, making use of the theories and concepts introduced in section 2.¹³

4.1 The Projects

The twelve projects included in this study are:

- **Natural Dyes Project:** an investigation into the possibilities for the use of natural dyes in Tanzanian industry. The project was executed between 1981 and 1990. The goals for the project were to conduct laboratory tests on procedures and techniques and give small-scale demonstrations on the extraction and use of these natural dyes.
- **Caustic Soda Project:** a research project focusing on the possibilities of local production of caustic soda by Tanzanian industry. The project was started in 1984 and ended in 1994, when the project was stopped after the creation of a pilot plant. Initially, the project focused on the batch production of caustic soda. Later it focused on continuous production of caustic soda. The goals for the project were to identify the procedures for the production of caustic soda, to design an appropriate production plant, and to develop and demonstrate domestic commercial production using locally available resources.
- **Aluminium Sulphate project:** a project on the production of aluminium sulphate for the use in local water purification. The project started in 1988 and ended in 1993. It was shelved due to the lack of interest of the NUWA (the Tanzanian water company), the organisation for which the investigation was started. The goals for the project were to identify and adapt processes for the production of aluminium sulphate, and to demonstrate the possibilities of using locally available resources.
- **Dehydrated Castor Oil project:** investigation of the production of Castor Oil using local castor seeds, for the use in e.g. the textile industry. The project was stopped due to a lack of materials and interest from both entrepreneurs and TIRDO management. Goals for the project were to identify and adapt the process for the production of Dehydrated Castor Oil.
- **Activated Carbon project:** a research project into the production of activated carbon using local waste materials, used within the food and beverages industries. The project was executed between 1992 and 1994, until it was shelved due to a lack of results from the laboratory investigation. Goals for the project were to identify and adapt the process for the production and demonstrate the quality of the local produced activated carbon.
- **Pectin project:** a project investigating the production of pectin using local waste materials for use by the food manufacturers in Tanzania. The project was executed between 1989 and 1992, and was stopped due to the insufficient quality of the produced pectin and the lack of funding. The goals for the project were to identify and adapt the process for the production of pectin and to demonstrate the quality of the pectin.
- **Refractories project:** investigation of the production of refractories using local materials. Refractories are widely used in all industries involving heating processes and heating facilities. The project was executed between 1988 and 1993, and was shelved due to the lack of outside funding. Goal for the project was to develop a process using specific available raw materials.
- **School Chalk project:** a project on the production of chalk using Morogoro Ceramic Ware waste gypsum and precipitated calcium carbonate from the caustic soda pilot plant. The project started in 1990, and was still going on in 1996. Goals for the project are the identification and adaptation of a process for the production, and the demonstration of its technical and financial viability
- **Wood Adhesive project:** Research into the production of wood adhesives using cashew nut shells. After initial research was finished, the project was extended with research into effective, locally available and safe preservative against insects and fungal decay for wood

¹³ Concepts from section 2 are italicised.

products. Research was started in 1989, and was still continuing in 1996. Though there was national and international interest for the project, no diffusion took place to industry. Goals set for the project are the identification and adaptation of a process for the production using cashew nut shells, identification of local and natural available fungicides, and the demonstration of the technical and financial viability of the production of the wood adhesives and fungicides.

- Solar Thermal Systems project: research project of thermal energy for drying (as main purpose). Within the project, the investigators try to combine specific needs of users with specific solar systems available. The project started in 1991, and was still not officially ended in 1996, though no further activities were being undertaken due to a lack of funding and lack of commitment from entrepreneurs. Goals for the project were to design, produce and stimulate the use of local systems of thermal drying.
- Satellite Receiver project: project for the local design of a satellite receiver for TV's. Project was started as follow-up of a satellite dish project. The project started in 1995, and was still going on in 1996. Goal was to produce simple receivers, producible with the equipment of the organisation.
- Turkey Red Oil project: a project on local the production of turkey red oil using local available castor seeds, used within the textile industry to dissolve dyes. The project was shelved due to lack of funding and lack of interest from the target group. Goals for the project is to identify and adapt a process for the production of the oil.

Some of the TIRDO projects explicitly focus on small scale enterprises (natural dyes project), others explicitly on large enterprises (continuous production of caustic soda). In most cases the technologies involved are rather small scale and both small scale and larger enterprises are targetted. As will be explained below, there is little detailed information on target groups, because this aspect of TIRDO's work has not received sufficient attention (see section 4.4).

4.2 Technology Identification and Selection

Central to the process of the technology selection is the question 'why'. What are the reasons for TIRDO to start with each of the projects and what is the justification for the project itself? To assess these question, one also has to look at who took the initiative for a project, whether and how a *needs assessment* was made and who performed the investigation.

For ten of the twelve projects examined, the initiative is taken by a member of the organisation or one of its governing bodies.¹⁴ Industrial firms only play a marginal role in the process of project selection. Table 2 gives an overview of the reasons given for undertaking a project. The identification of a project is most frequently motivated by import-substitution considerations and the availability of indigenous raw materials. In four cases, pressure from the management of the institute to produce a 'viable' proposal is mentioned as a motivation. In three cases only, is the initiative (partly) the result of contacts with (representatives of) industry.¹⁵

Table 2
Motives for Initiating Projects

<i>Motive</i>	<i>Times mentioned</i>
National shortages	2
Substitution of imports	9
Availability of raw materials	10
Contacts with industry	3
Follow-up research	3

¹⁴ Members were obliged to come forward with project proposals.

¹⁵ Contacts occur resulting from contract work and extension visits.

During the whole selection process entrepreneurs are hardly involved. At best, entrepreneurs are contacted by the investigator for technical information concerning the use of certain goods, materials and techniques within its production processes, both in terms of quality and quantity. This lack of involvement of productive enterprises is characteristic of all activities of TIRDO in the development of new technologies.

The project proposals are normally written by the principal researchers. They are responsible for the definition of the proposal, and they evaluate the technology and project as well. The quality of the proposals differs considerably due to the lack of standards for the writing up of projects. In some cases, the principal researcher got other members of the organisation involved, such as members of the information department, but this is not the rule.

All proposals give a short description of the technology involved, and occasionally discuss alternative technologies. The adaptability of the technologies by TIRDO- is TIRDO able to conduct the research - is normally investigated. Based upon the complexity and the type of technology and the capabilities of the organisation, the time, equipment and funding needed to master and adapt the technology are estimated. Normally a distinction is made between laboratory investigations and pilot investigations. All proposals specify the tasks to be executed within the project. Normally only technical tasks concerning development, production and testing are included.

With regard to the *appropriateness* of the project, two aspects are important: the technology's desirability for solving certain problems, and its suitability to certain aspects of the environment. Both these aspects are hardly investigated by TIRDO. Based on some characteristics of the technology, the expected effects are estimated by the principal researcher. It is rare for an economist, an entrepreneur or a social group from outside TIRDO to be involved in the investigation of appropriateness. Normally, only positive effects are mentioned; negative effects are simply ignored. Aspects of government policies and economic criteria such as import substitution, foreign exchange earnings and tax earnings, are regularly considered. For some projects, socio-economic aspects such as income-distribution and job opportunities are mentioned in the evaluation. Financial implications, e.g. the earning and investments for future entrepreneurs, are sometimes evaluated.

If a pilot plant is within the scope of a project, a division is made within the proposal (in the older projects the pilot plant is specified as separate project). Since TIRDO does not have the budget to develop technologies itself, budgets are specified in terms of donor contributions and TIRDO contributions (with TIRDO providing the staff for a project). After the approval of the projects by the council of TIRDO, the proposals are used to secure funding from donor agencies. The projects only start on a full scale after funds have been made available; Laboratory research normally starts earlier.

4.3 Acquisition of Technology

The technologies involved in the projects have some typical *characteristics*. The technologies are mostly old, always above five years of age, already studied world wide, and never considered to be of an advanced nature. In two cases, the technology was even not innovative for Tanzania. In the case of the caustic soda project, some components of the technology were found in the domestic economy. But this is an exception. In all other cases, acquisition of foreign technology is the rule. Normally, the aim of the project is process innovation. The technologies are mostly embodied in knowledge; knowledge concerning the process involved, its relation with the available materials and the desired output. Information needed for the project focuses on the process description, and information on the control of the process. Equipment consists of relatively simple locally available or locally producible equipment.

In the acquisition phase, it is mainly technical staff that is involved. Depending on the project and the activities within the acquisition process, chemical or mechanical personnel or a

combination of both participate. The involvement of non-technical staff occurs in half the cases, and is mostly limited to members of the information department.

Table 3 summarises the technology transfer mechanism used in the acquisition phase. Two important sources of knowledge are TIRDO's information department and public libraries. Foreign and domestic R&D institutes are also regularly used for the acquisition of knowledge and information, through training and documentation. The involvement of foreign or local companies is relatively low. When it occurs it is of a non-commercial nature.¹⁶ Regarding the *technology flow category*, free flow is by far the most important. Product embodied flow associated with the purchase of products occurs for projects in a pilot plant stage. Commercial technology acquisition occurs twice.

Table 3
Suppliers of Technology and Technology Flow Categories

<i>Technology supplier</i>	Times used	<i>Flow category</i>	<i>Relative importance</i>
Information department	9	Free flow	71%
Libraries	6	Sponsored flow	14%
Foreign companies	1	Flow accompanied with products	10%
Local companies	2	Commercial flow	4%
Foreign R&D institutes	3		
Local R&D institutes	2		
Other	1		

Notes n=12; importance of each flow mechanism measured on scale 1-5; relative importance based on average scores per mechanism (average score/summed average scores).

Usually, the organisation does not bargain with technology suppliers concerning the conditions for technology transfer, except in the case of acquisition of equipment. Costs for the acquisition of the technology usually seem to be low.¹⁷ Twice, larger expenditures were made for the setting up of pilot plants. A relatively small part of total project costs for the organisation are spent during acquisition. Costs identified include expenditures on travel, reproduction, and in some cases on equipment. In two cases, some indirect costs of an acquisition were indicated. Equipment, only acquired if funding is available, is mostly acquired locally. TIRDO tries to use or adapt local designs for its specific purposes. Only complex equipment, e.g. measuring equipment, valves and motors, is purchased from foreign suppliers. The project team approaches several suppliers, and selects on the basis of both technical and price specifications provided by prospective suppliers.

Concluding, it seems that the organisation acquires technology effectively, using an unpacking strategy. The technologies are acquired from different sources and mostly through free-flow channels. The technologies involved are suitable for this approach: old, well studied, embodied in knowledge and information and *unpackable*. The organisation has the *capabilities to unpack* the technology. Costs of this phase are relatively low, compared to total project costs. Bargaining activities are applied in the acquisition of equipment.

4.4 Adaptation

TIRDO's main interest in new technologies lies within this phase. We will discuss the activities in this phase, the input for adaptations, the adaptation goals and the results of the adaptation processes.

¹⁶ No costs being charged for acquisition, or knowledge being provided without profit.

¹⁷ Specific cost calculations for acquisition could hardly be made due to a lack of data.

The purpose of the adaptation phase, is to make a technology appropriate for its *target environment*. TIRDO's main aim in this phase is the adaptation of a technology to locally available raw materials (*characteristics of the target environment*). This has always been the main goal for projects executed by the chemical department. Aspects of the technological environment (available knowledge and equipment), the social environment (special social benefit groups) and the economic environment (financial implications), are sometimes mentioned as secondary goals of the adaptation process. The adaptive criteria tend to be related to physical aspects of the technology (*characteristics of selected technology*) and reflect the capabilities and areas of interest of the project team (*capabilities of adaptation team*). These interests are chiefly technical in nature.

Most staff involved in the adaptation phase comes from within the organisation. Besides the project team other departments are sometimes involved, especially during the pilot plant stage. The first part of the research, the laboratory investigation, is normally executed by the project team itself. Eighty percent of the involved staff are chemical and mechanical engineers. Within the organisation non-technical involvement in the adaptive work is very low. In two-thirds of the cases, actors from the environment (companies and other institutes) are involved in the work. This contribution is normally limited to the testing of materials. Only R&D institutes cooperate in the execution of the work itself.

The *success of an adaptation* is measured in terms of the extent to which the output of the project meets the expectations of the involved staff. We distinguish technical and non-technical expectations. Table 4 presents the scores on these items for the different projects. Whether a project has been shelved or whether its goals have been realised within the projected time and budget, is also indicated.

As indicated in table 4, the realised technical result often meets prior expectations. However, consideration of non-technical factors make the success of a project less clear-cut. Many researchers expect that there will be interest for the technology developed on the part of industrial enterprises and donors (industries are more interested in profitability, while donors are interested in the direct applicability). In practice, however, projects are often shelved due to lack of interest on the part of donors and industry. Other reasons for shelving projects are insufficient attention on the part of TIRDO's management and problems in purchasing raw materials. Insurperable technical problems hardly ever occur, except during pilot plant construction.¹⁸

Table 4
Success of the Adaptation Process

Project	Result met expectations		Shelved	Budget overrun	Time overrun
	Technical	Non-technical			
Activated carbon	6	3	Yes	No	No
Aluminium Sulphate	5	3	Yes	No	No
Castor Oil	5	1	Yes	No	No
Caustic Soda	8	4	No	Yes	Yes
Natural Dyes	6	2	No	No	Yes
Pectin	4	2	Yes	No	Yes
Refractories	5	3	Yes	No	No
School chalk	7	4	No	Yes	Yes
Solar systems	6	4	Yes	No	Yes
Turkey red oil	6	1	Yes	No	No
Wood adhesives	9	5	No	No	No
Average	6,1	2,9			

Note: Project results meeting technical and non-technical expectations both scaled from 1-10, n=11.

¹⁸ Both had problems with the designs and the implementation of the designs.

In case of shelved projects, the question whether results met expectations referred to the partial results. See Appendix A, variable IV for details of scale construction.

Budget-overruns hardly ever occur, due to strict financial project control. Only for projects in a pilot plant phase, have minor overruns been recorded. In half the cases, the research (or part of the research) extended beyond the initially proposed period. Reasons given for this are that researchers cannot focus sufficiently on a project, acute financial problems, and lack of results.

In sum, TIRDO usually executes the adaptations from a narrow technical point of view. From this technical viewpoint, the participation of staff is sufficient, the selection of aspects for adaptations is in line with the staff's capabilities and the results are good. However, due to this one-sided input of capabilities, the technologies are not sufficiently adapted in a broader sense. Financial, economic and social aspects are not included in this phase, and the technologies are not appropriate for domestic industry.

4.4 Selection of firms

This paragraph focuses on one of the activities most underrated by TIRDO's management: the 'selling' of a technology to local industry. Within the R&D organisation there is still a widespread belief that sooner or later adequate technologies should and will sell themselves. The dependent variable in the selection phase is the number of firms persuaded to adopt an innovation, which are actually selected for technology transfer.

Only a few projects reach the phase where TIRDO searches for entrepreneurs interested in adopting the innovation. Most projects are shelved before this phase is reached. Only in five projects have diffusion activities actually taken place (Natural Dyes, Caustic Soda, School Chalk, Wood Adhesives and Solar Systems -projects). In three other projects (Aluminium Sulphate, Pectin and Refractories) some promotional activities have taken place during an initial stage of the project.

We divide the selection activities into *activities to interest entrepreneurs* in an innovation and *activities to persuade entrepreneurs* to adopt the innovation. Table 5 summarises the different methods used. To create interest in the projects, TIRDO uses a combination of *general* and *selective communication instruments*. Selective communication instruments are preferred by the organisation. The target group of firms is based upon the expected use of certain goods within their current production processes.¹⁹ For two projects, the School Chalk and the Wood Adhesives project, a market survey has been performed to analyse a target group for the innovation.

Table 5
Interest Creating Activities and Instruments for Persuasion

<i>(a) Methods for initial interest</i>		<i>(b) Methods for persuasion</i>	
Method	Times used	Method	Times used
Publication	2	Free consultancy	2
Radio & TV	2	Technology ownership	1
Trade-fairs	3	Support in loan securing	2
Workshops	3	Financial stimuli	1
Direct communication through extension officer	5	Private guidance	2
Direct mailing	3	Taylor made (re)design	4
Other	2	Result insurance	2
		Pilot plant implementation	2

Note: n=8

¹⁹ For example, for Caustic Soda production, TIRDO expected the producers of soap to use the technology in their production process; for wood adhesives, the producers of particle board.

Some activities are undertaken to persuade the enterprises to accept an innovation, by reducing entrepreneurs' uncertainties. The tailor-made design of production systems based upon the specific needs of the entrepreneurs is mentioned in four projects (*specific instruments of persuasion*). One method, though not specifically mentioned, is subsidising the use of a technology. The R&D organisation does not try to recover the total development costs of a technology, only charging direct costs and (usually) some fixed fee for development costs.

Besides the project team, the information department is involved in 60 per cent of the projects. In some cases, members of the information department participate in the work of the project team, in some other cases their involvement is on request and is limited to selectively approaching some entrepreneurs.

The number of interested firms differs considerably across the projects. The number of instruments TIRDO uses to interest and persuade also differs from project to project, and a relation between the instruments used and number of firms expressing interest seems evident. As indicated, the total activities for technology diffusion are modest. The organisation does not put enough effort into interesting and motivating entrepreneurs. So far, no firms have been persuaded to adopt an innovation. Therefore, no firms have been selected for transfer of technology. One may conclude that TIRDO's execution of the selection phase is not very effective.

4.5 Transfer and Implementation

In the survey study, the transfer and implementation phases have not been formally included, as no project had progressed up to the stage that the innovation was actually being transferred to firms in the target group. For the two case studies investigated in more detail, natural dyes and caustic soda, some remarks regarding transfer and implementation, were made by persons involved in these projects. These remarks focus on the plans the R&D organisation had formulated for the transfer of the innovations. However, at the time of writing no transfer had been actually realised.

For the natural dyes project, it is indicated by participants that TIRDO assumed that the SIDO (Small Industries Development Organisation), the organisation with which they co-operated in this project, would take the lead in the transfer and implementation phase. TIRDO only would be involved in the transfer of the technical aspects of the innovation to SIDO. It was also prepared to give support in the implementation of the pilot plant. SIDO was to serve as the *agent* for technology transfer and it was expected to have sufficient capabilities and experience in technology transfer processes. For TIRDO, the main focus within the knowledge transfer phase was on the design of equipment and plant. Production management was not included. Apart from the fact that SIDO was expected to have the required management expertise, TIRDO itself certainly did not possess the knowledge of how to run a plant.

In the case of the caustic soda project there was also no transfer of the innovation. The staff did indicate what the implications of technology transfer would be. They described the equipment and knowledge prerequisites for transfer in general terms. (e.g. "... are expected to have 'feeling for chemicals'."). There was interest on the part of firms, a pilot plant was in operation and one entrepreneur seemed to be willing to adopt the technology. However, the worsening economic climate and decreasing prospects of protection of domestic industry, prevented the entrepreneur from following up on his interest.

A few remarks are in order concerning two instruments which are of importance for the diffusion of technology in the last three phases of technology development projects: the use of *change agents* and making use of *contacts within industrial networks*. Change agents are normally not used in TIRDO projects. Only in one case, the School Chalk project, could a kind of change agent be identified: one member of the project team focused on supporting all entrepreneurs with the different aspects of the innovation decision.²⁰

²⁰ A Dutch student temporarily involved in the project.

Contacts with firms and individuals within a well developed industrial network can contribute positively to the selection of a technology for development and the subsequent success in the diffusion of the innovation.²¹ The involvement of networks in TIRDO's projects turns out to be low. Direct influence of domestic industry on project content and on activities of project teams is lacking. Though there are some contacts with industrial firms in most of the projects investigated, the scope of these contacts is limited.

4.6 General Characteristics of the Technology Development Process

As no transfer or implementation of technology has taken place during the period studied, it is not possible to measure the overall success of the projects in terms of the numbers of successful adoptions. In this section, we use the interest expressed by entrepreneurs in a project and stage the negotiations between TIRDO and entrepreneurs have reached, as proxy measures of success

Table 6 summarises five important variables characterising the four evaluated phases of the technology development process: assessment of existing needs (I) and appropriateness (II) in the technology identification and selection phase, care exercised in acquisition (III), success in adaptation (IV) and use of diffusion instruments in the firm selection phase (V). The table also presents a rough proxy variable for project success (VI) based on the interest in an innovation and the stage the negotiations concerning the innovation have reached. The variables are based on the survey returns. The scaling of the variables is briefly described in Annex I and in more detail in Bongenaar (1997). The scaling procedures are rough and should not be given any precise mathematical interpretation. Nevertheless, they provide useful summary indicators of activities in different phases of the technology development process.

Only the acquisition phase has an average score of more than 6. Two variables have very low scores: the assessment of existing needs (I) and the variable relating to the diffusion activities in the firm selection phase (V). This indicates that the main problems in project execution are concentrated within these two phases. Both phases refer to the interactions between the institute and its environment and indicate that this interaction does not taken place as often and as intensively, as required.²²

Table 6
Main Variables for the Success of the Technology Development Process in Different Phases

<i>Project</i>	<i>Assessment Existing needs</i> <i>I</i>	<i>Appropriate</i> <i>II</i>	<i>Acquisition</i> <i>III</i>	<i>Adaptation</i> <i>IV</i>	<i>Activities for diffusion</i> <i>V</i>	<i>Success project</i> <i>VI</i>
Aluminium sulphate	3	6	8	4	1,5	2
Caustic soda	2,5	6	6	4	10	7
Natural dyes	2	5	7	6	1,5	6
Castor oil	1,5	1,5	5	3	-	1
Activated carbon	3	5	7	5	-	1
Pectin	2	6	6	3	1,5	2
Refractories	3	4	5	4	1	3
School chalk	2	7,5	7	6	8,5	8
Wood adhesives	3,5	7,5	8	7	6	7
Solar systems	4	7,5	7	5	1,5	7

²¹ Other positive effects, in acquisition and adaptation of the technology can be expected as well.

²² This notion also came forward discussing the organisation and the Tanzanian R&D sector. It therefore is likely that this problem is general for the other R&D institutes as well.

Satellite receivers	1,5	5	8	-	-	1
Turkey red oil	7,5	4	6	4	-	2
Average 1)	3	5,4	6,7	4,5	3,9	3,9

Note 1) Calculated with respectively n =12, n=12, n=12, n=11, n=8, n=12. The variables are roughly scaled from a negative pole of 1 to a positive pole of 10.

Inspection of the individual projects indicates that their scores in the different phases tend to be related. 'Good' projects tend to score well on most variables. The School Chalk, Wood Adhesives and solar systems are examples of such projects. The Castor Oil, Activated Carbon and Refractories projects are examples of 'bad' projects. This suggests that the inter-phase relationships are also very important. Nevertheless, irrespective of the project, specific phases of the technology development process tend to have much lower scores than the other phases.

5. Conclusions and Recommendations

The Research and Development Organisation TIRDO is successful to the extent that members of the organisation succeed in developing technologies that meet their expectations in a technical sense. Relative success in the technical sphere, however, has not led to the diffusion of the technologies to the target group, as originally intended.

One possible explanation for this phenomenon is the general lack of innovativeness of Tanzanian industrial enterprises, struggling to survive in a difficult environment. During the period studied, many parastatals were being privatised, industrial production was stagnating and there were serious financial constraints which hampered innovativeness. Small scale enterprises in particular lacked the financial and human resources to innovate. The innovativeness of enterprises was not the focus of this investigation, though it is obviously a relevant factor. However, the research reported on in this paper indicates that lack of success in technology diffusion is also related to the lack of sufficient activities to align TIRDO's activities to the expectations and needs of domestic industrial organisations.

To start with positive findings, both the acquisition and the technical adaptation activities are fairly successful. The acquisition of technology is performed reasonably well by TIRDO. Technologies involved in the technology development processes are normally old, and processes are described in publicly accessible information. The technical staff members involved are well educated in the field of their technical specialisation and the information department of the organisation is experienced in the search for information on the international market. The technologies acquired are unpackable and the acquisition teams have the capacity to unpack technologies. As for the output of the adaptation phase, in most projects the implemented adaptations functioned according to the expectations of the organisation, and the projects were regarded as technically successful. Finally, in spite of a marked lack of success in diffusion of technology, one could argue that the experience of fairly successful acquisition and adaptation of technologies in TIRDO has contributed to the building up of technological capabilities within the institute. These technological capabilities are of potential value in future stages of industrial development.

Nevertheless, a successful technology development path involves more aspects than those mentioned above. The selection of projects is usually not based to the technological needs of domestic industry. Needs, if indicated in a project, refer to possible uses of the intended output of the technology and are based upon national indicators and policy documents. They are seldom related to specific requests from industrial firms. Initiatives for the identification of technologies tend to be taken by members of the TIRDO staff, rather than by the target group. A successful R&D institute should use industry's needs for technology as a starting point in the development process. The organisation should take measures to intensify communication with the industry and its management should formulate procedures and translate the needs of industry into viable projects. Direct influence of several entrepreneurs on the definition of projects should be encouraged.

The organisation hardly evaluates the appropriateness of technologies for the Tanzanian environment. The organisation should pay more attention to evaluations of appropriateness, as they influence both the chances of successful adoption of a technology, and the efforts required for its adaptation. To this end, three main actions should be taken: laying down fixed procedures for the evaluation of projects, involving non technical staff in the evaluation process and using these evaluation results in management's decisionmaking.

TIRDO makes little use of instruments to interest entrepreneurs and to persuade them to adopt an innovation. Few efforts are made to interest and persuade entrepreneurs and there is no consistent policy underlying these efforts. As a result, there is little interest on the part of entrepreneurs and few entrepreneurs are persuaded to adopt new technologies. The lack of activities in this phase is partly due to the institution's assumption that good technologies should sell themselves. TIRDO does not consider it necessary to improve the process of diffusion, since, in its opinion, the lack of diffusion is mainly a problem of the domestic entrepreneurs. On the basis of the analysis in this paper, the organisation should focus on intensifying diffusion activities both in terms of quantity and quality. Clear policy procedures are needed, indicating the persons or groups responsible for policy execution.

The absence of involvement of non-technical personnel in projects can be noted in several phases of technology development projects. This results in a one-sided view on technologies. The organisation should take steps to ensure that different capabilities are represented in each project team. In addition to technical expertise, economic, social and communicative expertise is needed in all phases of project execution. If the organisation is not able to provide these non-technical capabilities, it should try to cooperate with domestic organisations which do have such capabilities.

A weakly developed industrial network and lack of linkages with domestic industry seem be factors with an overall negative influence on different aspects of the innovation process (Meeus and Oerlemans, 1993). The organisation should step up its efforts to extend its industrial network. Frequency and intensity of contacts should be increased. In the execution of projects, the organisation should seek co-operation with domestic industry and with other (local) technical and non-technical institutes.

Research and development institutes should regard the marketing of the technologies as an essential element of research and development work. Marketing activities should commence before a project is initiated, and should continue to influence the work during the complete span of a project. Technologies should not be regarded as successful on their own merits, but should be judged to the extent they succeed in serving even a technologically conservative Tanzanian industry's needs and expectations. Only under such conditions will firms consider adopting TIRDO technologies.

Finally, the organisation should try learn from past experiences, and to use these experiences to improve the execution of future projects. After completion or shelving of projects, the management should make a final evaluation of the project execution and adjust its policy for future projects, accordingly.

Most of these recommendations will not require supplementary funding. More important are changes in mentality of management and staff. Instead of tending to regard domestic industry as backward and uninterested in (local) technologies, one should investigate why firms failed to adopt the technologies developed within the organisation. TIRDO should start by improving the activities within the present resources of the organisation.

Several of the issues and problems analysed in this paper are of wider relevance for technology development in research and development institutes in developing economies. Though our limited data do not allow for strong inferences, our results are consistent with findings in the literature. The importance of industrial networks, needs assessments, appropriateness of technologies and marketing are mentioned in many studies, as essential to the successful diffusion of innovations. Giving higher priorities to these aspects of technology development could lead to a more efficient and effective use of resources invested in the research and development sector.

Annex A: Construction of the Variables

The variables I-V in table 6 are composite variables. The score of each project is the average of the composite variable scores calculated from the questionnaires completed by the principle project researchers, and a questionnaire completed by the first author, based upon his analysis of the project files. For more details see Bongenaar 1997, appendix B.

I. Assessment of existing needs (scale 1-10)

The composite variable score is the average of scores on three variables, each scaled from one to ten.

- Initiative taken by the organisation versus initiative taken by industry (Scale 1-10; 1: TIRDO - 10: industry)
- Initiative motivated by expressed needs of firms or motivated from within the organisation (Scale 1-10; 1: no needs assessment - TIRDO internal need assessment - government - 10: expressed needs)
- Degree of influence of target group in this phase (scale 1-10; 1 no influence; 10 maximal influence)

II. Appropriateness (scale 1-10)

The composite variable score is the sum of scores for two variables:

- Extensiveness of the investigation of appropriateness, measured in terms of the number of appropriateness criteria mentioned (scale 0-5; number of criteria mentioned divided by four, maximum number mentioned 20)
- Indicated appropriateness of the technology, measured by average indicated appropriateness of the technology on a maximum number of 20 criteria of appropriateness (scale 1-5, after rescaling of average scores to a 1-5 range)

III. Careful acquisition of technology (scale 1-10)

The composite variable score is the sum of scores for two variables:

- Unpackability: the possibilities of unpacking a technology (scale 1-5; 1: difficult to unpack - 5: easy to unpack).

The unpackability scale scores are the average of the scores on the following three items: age of technology (1: young - 5: old), familiarity of technology (1: hardly studied - 5: widely studied) and accessibility (1: mainly private - 5: mainly public).

- Unpacking capabilities: the capabilities of the project team to unpack a technology reflecting technical capabilities and non-technical capabilities (scale 0-5, after rescaling of scores to a 0-5 range).

IV. Degree of success in adaptation (scale 1-10)

The composite variable score is the average of two variables:

- Project result fulfilled technical expectations (Scale 1-10; 1: Did not fulfil expectations - 10: Completely fulfilled expectations). These scores are based upon the scores of 8 items, with a scale of 1-4, which are averaged and rescaled to a 1-10 range).
- Project result fulfilled non-technical expectations (Scale 1-10, 1: Did not fulfil expectations - 10: Completely fulfilled expectations). The score of this variable is based upon 8 items with a scale of 1-4, averaged and rescaled to 1-10.

V. Use of diffusion instruments (Scale 1-10)

The composite variable score is the sum of scores for two variables:

- Use of awareness creating instruments in a project, to create awareness of the technology amongst members of its target group (initial interest) (scale 0-5, number of instruments used divided by maximum number of instruments, rescaled to 0-5)
- Use of persuasion instruments used in a project, to persuade members of the target group to adopt a technology (scale 0-5, number of instruments used divided by maximum number of instruments, rescaled to 0-5)

VI. Success of the project (scale 1-10):

This variable reflects the judgement of the investigator concerning the degree of interest of firms in an innovation. (1 no interest expressed by any firm - 10 adoption by at least one firm). The score is in turn based on:

- The number of firms showing some interest in an innovation
- The stage of negotiations reached regarding an adoption decision.

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