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Technology transfer as a learning and developmental process: an analysis of Norwegian programmes on technology transfer

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Abstract

This paper focuses on understanding technology transfer. The point of departure is to construct a model for transfer of technology based on organizational theory. The model identifies the transfer as a socio-technical learning and developmental process (TLD process). Technology is understood as a social construction where human choice and values determine the outcome. A successful transfer of new technology depends on a socio-technical change process, where the success is reached when the local company profitably integrates technology in its day-to-day operation.

The TLD model is used as the basis for an empirical analysis of Norwegian programmes on technology transfer. This work is introduced by giving an overview of the literature evaluating the programmes. This literature, strongly influenced by qualitative methodology, does not give much insight into the basic elements of the TLD process. Therefore, the next step in the research is to investigate the models for the programmes in operation.

The main conclusion is that no programme design is consciously based on understanding technology transfer as a socio-technical learning and developmental process. Firstly, technology is usually considered as a material artefact and not as a carrier of knowledge and cultural values. Secondly, the traditional developmental model is bureaucratic and top-down. The intention is to furnish companies with technology and not to let the potential use of new technology be integrated into a planned learning and developmental process.

The key point in this paper is to advocate that policymakers and managers of technology transfer programmes redesign their programmes to incorporate the important and necessary learning and developmental processes. If this is taken seriously, it will be possible to take full advantage of technology transfer as an important element in technology policy.

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1. Introduction

The Norwegian economy is characterized by a high influx of small and medium sized enterprises (SMEs) and relatively few big enterprises producing raw materials for export markets.[1] This far-reaching country — if twisted around the southern point the North Cape will touch Rome — is bound to have regional economic challenges. Since the Second World War it has been public policy to keep the regional economies viable. Several different types of public support programme have, over the years, been in operation to achieve this goal. In the last two decades Norwegian public and semi-public agencies have initiated several policies supporting transfer of technology. Programmes were launched as instruments aiming to increase the competitiveness of SMEs. A rich variety of programmes on technology transfer exist in Norway [1]. This creates a good basis for analysing the operational characteristics of programmes.

The main objective of this paper is to enquire into the factual content of technology transfer. I will position my analysis within the framework of organizational theory. In taking this stand, it is important to examine technology transfer processes as human activity. Much of the literature analysing technology transfer focuses on the international exchange dimension and, as Gibson *et al.* [2] state in their bibliography, ". . . noteworthy was the virtual absence of articles with a communication perspective . . .". In this paper I will challenge two positions that are normally taken for granted. Firstly, technology is not merely understood as a scientific artefact. The intent is to conceptualize technology as a social construct. Secondly, the transfer of technology is re-examined as a learning and developmental process. Merging these two positions, a theory of technology transfer is developed and used as a tool for analysing Norwegian programmes on technology transfer.

2. Technology transfer as a socio-technical learning and developmental process

To begin with, technology transfer seems pretty straightforward. Taking the position of the layman, the issue is to move machines, equipment and tools from one location to another. Technology is understood as a material element or artefact. The transfer process is seen simply as moving equipment from a supplier to a user. Little or no attention is paid to implementation and use of the new technology. When properly installed, it is per definition operational. Viewed in the light of organization theory, this position needs to be examined more carefully. Both 'technology' and 'transfer' need a proper professional clarification.

Traditionally, technology is usually conceptualized as in Webster's dictionary [3]: "the science or study of the practical or industrial arts, applied science". This definition identifies technology as knowledge, but does not capture the layman's notion of the physical hardware. Reviewing the literature, three levels of meaning are identified [4]:

- the physical objects or artefacts;
- the process of making artefacts;
- the knowledge necessary to operate the artefacts.

Technology is, according to this definition, an integration of physical objects, the process of making the objects and the meaning associated with the physical objects. These elements are not distinctive and separable factors, but form a 'seamless web' that constitutes technology [5]. In an analysis of technology all three variables must be understood as being related to each other. A change in one element affects the other two. The second important point implied in this concept is an understanding of technology as a social product. The physical objects are created by human beings on the basis of values and human choice [6, 7]. The developmental process of new technology is not sequential, but one of "alternation and of variation and selection" [8]. The resulting physical artefact develops out of the final phase in which members of the team share the same understanding and meaning of what the new technology should look like.

According to this argument, knowledge will constitute an inseparable element of any technological artefact. A machine or a tool will accordingly have embedded in it a cultural meaning simply because the actors involved in design and production have made it operational under specific cultural conditions. Using the artefacts will, of course, demand access to this cultural knowledge. Some of this knowledge is explicable using language. On the other hand, the art of designing and producing technology involves more complex human processes. Polanyi [9] argues for the 'tacit' dimension in human reasoning. The implication is, of course, that we know more than we can describe using language. Collins [10] uses the tacit dimension to develop a concept of 'cultural skills' which he defines as "the ability to understand and use facts, rules, and heuristic". Cultural skills will accordingly be necessary prerequisites to enable one to successfully develop or use technological artefacts.

The argument so far has led to a conclusion that technology is a social product, and that the use of technology requires access to the cultural knowledge encapsulated in technological artefacts. Technology transfer is therefore a socio-technical process implying the transfer of cultural skills accompanying the movement of machinery, equipment and tools. Transfer of technology is both the physical movement of artefacts and also, at the same time, transfer of the embedded cultural skills. Local actors, to whom the technology presumably is moved, must acquire the necessary skills and understanding through a learning process. A learning process cannot be implanted in the same way as a physical body is moved, but follows the logic of human development.

The transfer of technology consists of two opposing processes. Seen by the supplier, it encompasses both the shipment of merchandise and the transfer of necessary knowledge to operate the equipment. From the position of the receiver, the process involves acquiring material artefacts and managing the learning process necessary to operate the equipment. A contradiction is, of course, that transfer of knowledge as seen by the vendor can have a very different meaning from learning how to operate the equipment as seen from the user side. The implication is that the cultural skills associated with technology are not one-dimensional. It is not obvious that vendors have the knowledge that the users request, and it may be doubtful that the potential user understands the opportunities given by the technology as seen by the vendor. A successful transfer process must bridge the gap between clarifying, for the user, the potential of the technology, and the supplier's ability to provide the necessary cultural skills for operating it.[2]

To summarize the argument so far, technology transfer requires an innovation process leading to the successful use of new machines and equipment. This innovation process involves more than merely implementing the new technology into an already existing organization. Using the term 'implementation' might imply a passive adaptation to a given technology. It is also important to point out that the argument goes beyond understanding technology transfer as a communication process as identified by Williams and Gibson [2]. The use of the term socio-technical process indicates a more active developmental process. Technological artefacts can be adjusted to fit local conditions, and the organization of work can be developed to take advantage of the potential given by the technology. The socio-technical dimension has a double meaning, indicating not only the inseparable relationship between artefacts and cultural skills but also the more traditional interrelationship between technology and organization.[3]

Transfer of technology to an organization implies that the user has to acquire the necessary skills to be able to operate the machines and equipment. It is easy to conceive this as a learning process where the users are trained to operate the new technology. Therefore, it is obviously a *learning process* aiming to close the gap between technology and the embedded cultural skills necessary for this operation. But technology transfer also has a second socio-technical dimension. The user company's organization has to take full advantage of the technology transferred, or must develop the potential to do so. This is a process involving possible major organizational changes. Therefore, technology transfer implies a more profound *developmental process* in the user company.[4] A third socio-technical argument is that technology should never be considered as a given entity. I have already argued for the social shaping of technology. In a transfer process it is also important to be aware that technology must be adjusted to the local context. The supplier, either a vendor or a technology developer, must have the ability to assess the user's needs and be able to adjust the technology accordingly. Therefore it is also a *learning process* for the supplier of machines and equipment.

Transfer of technology is a social innovation process depending on the user organization's capacity to learn. Consequently, technology transfer should be denoted a *socio-technical learning and developmental process* (TLD). In short, it is a social innovation process whose capacity to exploit the technological artefact is the focal point.

3. Technology transfer as a socio-technical learning and developmental process (TLD)

The argument so far identifies technology transfer as a socio-technical learning and developmental process. A programme aimed at supporting technology transfer is in itself an organizational entity purposely designed to support the distribution of technology to the user. Investigating more closely, it seems reasonable to identify three distinct groups of actors.

Viewing programmes on technology transfer as organizational units permits us to focus on operational characteristics and processes. A programme has a superstructure responsible for planning, coordinating, mediating and executing activities. This is identified as the *programme level*. The 'bottom line' effect of technology transfer is measured by success in implementation at a specific organizational setting. The usefulness of new technology will be immanent only in terms of its application in the user company. This identifies the *user level*. Technology originates somewhere. A programme's main purpose can be understood as connecting a technology source to a potential user. This intermediary level is identified as the *supplier level*.

Traditionally, in the literature, a programme on technology transfer is visualized as a one-way sequential process. A programme administration has hierarchical control over the programme, identifies and activates relevant suppliers of technology, and designs a mediating process that channels technology to user enterprises. The local implementation follows the acquisition of new technology. Simplified, this sequential model is shown in Fig. 1.

The programme level incorporates the national and regional diffusion and initiation activities. On this level the analysis must deal with the general policy of the programme. An important programme variable is the strategy for disseminating the technology to the participating companies. This I would identify as the mediation process. Important decisions at the programme level are how to screen the population for possible candidates, how to motivate or engage companies to join in, and how to centrally support or initiate the local 'bring into use' process.

At the user level the challenge is really to be sure that technology is implemented. First of all, appropriate technology has to be chosen. Technology must be both economically feasible and adequate for the user company. Secondly, both management and operators have to acquire the necessary skills to operate the new technology. An important question is how the user acquires the necessary skills for operating the new equipment.

Technology transfer implies, of course, that technology is 'moved' from somewhere to someone. The sources of technology are indicated as the supplier level. According to the earlier discussion, technology is understood as material

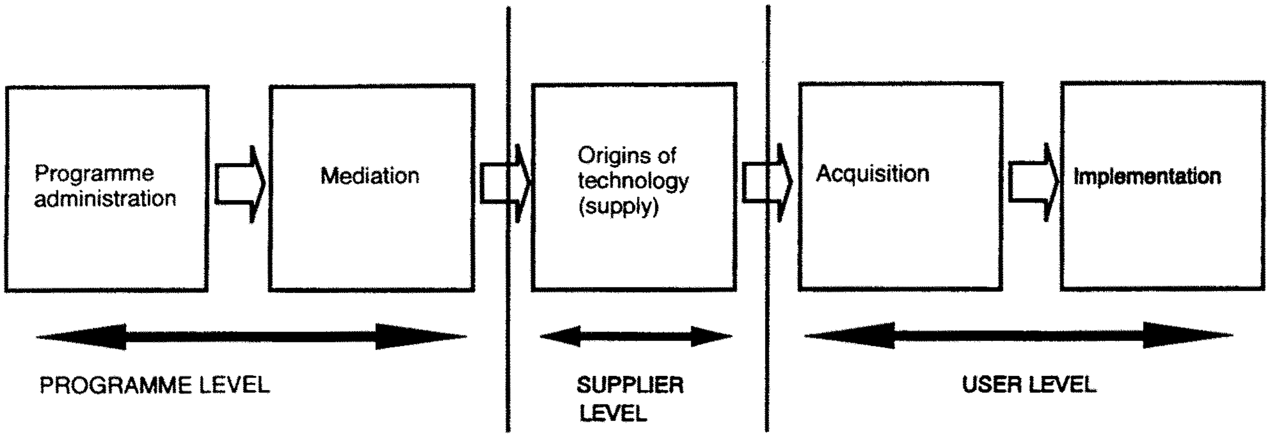

Fig. 1. The sequential model for technology transfer.

artefacts, the process of making artefacts, and the knowledge necessary to operate the artefacts. There is a wide variety of possible suppliers, ranging from vendors importing machines and tools to national research laboratories developing new technology.

The basic problem with the sequential model of technology transfer is the omittance of learning feedback loops and the absence of reflections on its socio-technical nature. A reconceptualization of programmes, understood as a technology-based learning and developmental process, is shown in Fig. 2.

The important element in this concept is the identification of the circular innovation–acquisition–supplier interaction process. This loop identifies the core elements in a learning and developmental process. Obviously, these are all socio-technical processes. Three other changes have also been made in developing this model. Implementation has been expanded to a more general term of innovation. The reason is, of course, to call attention to a much broader progress than is implied by implementation. The 'learning and developmental' notion identifies both individual and organizational learning processes [11, 12].

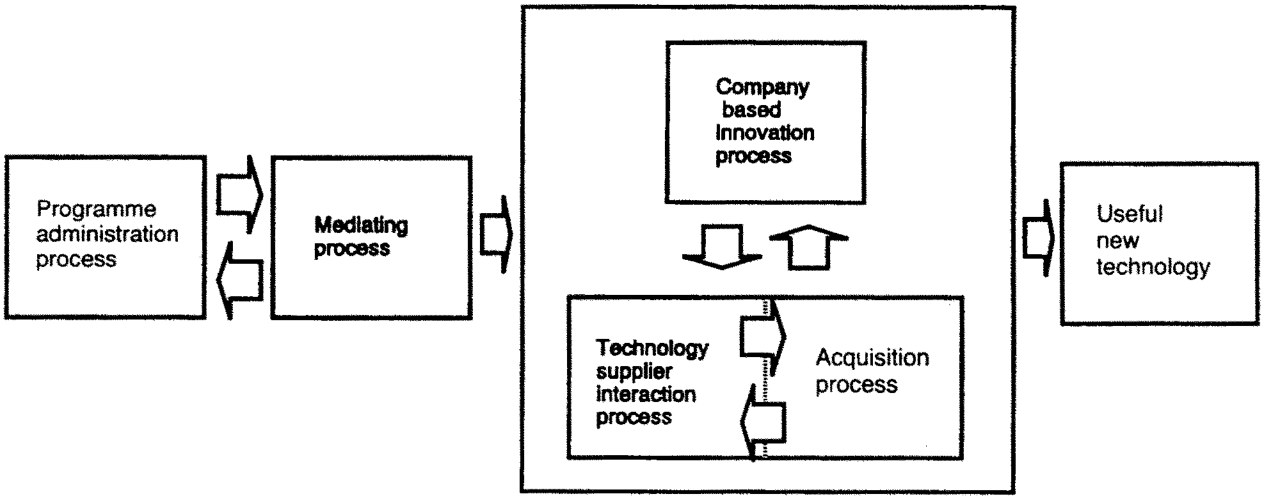

Fig. 2. Technology transfer as a socio-technical learning and developmental process.

By using 'innovation', the intention is also to underline the fact that technology transfer must integrate with the continuing adaptation of organizations to changing contingencies. Utilizing new technology requires new organizational routines, new local knowledge and new contextual knowledge [13, 14]. It is also important to make it clear that I understand the innovation process as being more complex than in the rational decision models argued for by, for example, Zaltman, Duncan and Holbek [15]. In line with Burns and Stalker [16], my argument is that organizational characteristics impact the innovation capability. An 'organic' organization is beneficial, permitting creative and adaptive activity. Innovation is also understood as a field where organizations can achieve mastery through systematic work. Bujis [17] frames it neatly in the words "Innovation can be thought". Systematic training in improving the innovation capacity of an organization will certainly improve the operation of any programme of technology transfer.

In this model, relationships between processes are identified as a reciprocal interaction. The core learning circle in technology transfer is constituted by the company-based innovation process, the supplier interaction process, and the acquisition process.[5] This total innovation process can be supported in different ways. Usually, an outside consultant or researcher interacts with the enterprise in order to assess the possibility of introducing new technology. In this process it is important to understand the dynamic relationship between the 'outside' technology expert and the 'inside' employees of the company. Elden and Levin [18] identify this as a cogenerative learning process, where both actor groups develop new knowledge based on the dialogic relationship. The suppliers should also be brought into this ongoing dialogic learning process. Smart investment in new technology should be based on the discovery of useful and profitable technology for the company. This is a two-sided challenge. Useful and profitable technology for a company can be identified by looking at what technological options are available, which means that the supplier offers whatever is on the shelf. On the other hand, the artefacts on the shelf can be modified to better suit the needs of the company if the supplier has a real understanding of the company's needs. A successful selection can best be achieved through mutual learning between user and supplier. The supplier learns of the company's needs and the user learns to understand the potential of the new technology. The acquisition process should go hand in hand with the innovation process. Introducing new technology comprises the moving of artefacts to the enterprise, the acquisition of the cultural skills necessary for its operation, and the development of the whole organization to best comply with the new demands and possibilities given by the new technology. Again, the argument focuses on supporting the local change process. I will, in the continuation of this paper, discuss the acquisition process as an integrated part of the relationship between technology supplier and user.

Operating a programme on technology transfer requires overall coordination and control. That is certainly embedded in the administrative function. An important element of the administrative tasks is the mediating process, bringing companies into the programme or diffusing the programme to potential user companies. A bureaucratic attitude to this task will be first to work out a plan for the whole programme and then to start implementing it. This may not be the most effective way to go about transferring technology. An alternative concept of a programme is to understand it as a changing organizational structure. Monitoring the achieved results will give input for directing or redirecting the efforts. Consequently, the programme administration should always monitor the results and have the organizational capability to adjust the operational characteristics to meet the goals [19–22]. The monitoring function usually takes the form of evaluation. This will play an important role in running a programme if the results are fed back to the administrators on a continuous basis. In this manner it not only opens up a fast response to operational challenges, but also constitutes a continuous learning process for the programme's administration.

A programme on technology transfer is certainly a technology-based learning and developmental process at the company level. This is identified as the user's innovation process. At the same time, the programme is also a learning process for the programme's administration. Consequently, a programme should never be conceived as static, solving a one-time defined problem. A programme on technology transfer is a continuously and dynamically changing activity in which goals and operating characteristics change as learning leads to improved operation. Technology transfer at the company level is an innovation process, and the programme itself should be considered as an innovation process.

I have now argued for a frame of reference focusing on learning and developmental processes. The focal point for the continuing discussion is that learning can be achieved by applying this philosophy to an analysis of Norwegian programmes on technology transfer.

4. Research methodology

This research was based on several different types of data. Firstly, the work done in the formative evaluation of a Norwegian programme on technology transfer (the BUNT programme), carried out over the last three and a half years, has provided contact with the field. A group of three researchers and seven PhD students at the Norwegian Institute of Technology at the University of Trondheim has, during the last three years, been engaged in evaluation and research work on technology transfer [23]. The aim of this work is to carry out traditional research, but also to produce useful knowledge on the developing project, thus giving the administration the possibility to adjust the programme to best achieve the desired goals. Results of this formative work have been published in several reports. Over the period of operation the research group has collected an extensive amount of data, both at the programme and at the company level. Fragments of this knowledge are used as the background for this paper.

Secondly, all obtainable presentations and descriptions of Norwegian programmes on technology transfer have been collected. Through a systematic scanning procedure, all programmes in operation were identified. The administrators of the programmes were contacted and asked for all available information, including possible evaluations. After piecing this information together, the researchers made a written statement for each programme. This was sent back to the respective administrations for corrections. The results of this work were first published by Klev and Levin [1] and later updated for this paper.

The third source of data was the literature based on evaluations of programmes. The field was scanned, and all available evaluations were collected. An extensive summary of these evaluations is given in Torvatn and Rønningsbakk [24].

The methodology for analysing data is basically qualitative. Glaser and Strauss's [25] and Strauss and Corbin's [26] concepts of grounded theory building have guided my work. An attempt to link practical experience from evaluating the BUNT programme with Norwegian evaluations on programmes for technology transfer, and the international literature, resulted in the understanding presented in this paper. Rigour in the qualitative analysis followed guidelines given by Miles and Huberman [27], Piore [28] and Miles [29].

5. Norwegian programmes on technology transfer

A survey made in 1989 by Klev and Levin [1] identified twelve different Norwegian programmes on technology transfer. In 1989 the government spent more than NOK 200 million on technology transfer. Most of the programmes were designed for small and medium sized companies. Table 1 gives an overview of the situation. In the Appendix a brief description is made of each programme.

The first eight programmes involved public funds for purchasing material artefacts of technology, i.e. machines, tools, and other kinds of hardware. The next four programmes focus basically on improving local competence development.

TABLE 1. Costs of Norwegian programmes on technology transfer (all figures in NOK 1 000 000)[1]

No.	Programme	Period	1988	1989	1990
I	SMB-U	1987–91	30	31	
II	NT	1987–91	25	25	25
III	NSP	1978–91	6	6	6
IV	FUNN	1988–92	18	40	30
V	IPS	1988–92	10	26	18
VI	DTS	1989–94		12	12
VII	BUNT	1989–92		16	20
VIII	MARIN BIOTEK	1988–	15	15	15
IX	IDESØK[1]	1986–	3	3	
X	LOS	1988–91	10	15	10
XI	VERKSTEDPROG	1987–90	3.5	3.5	
XII	IND.ATT	1984–	12	12	12
Total			132.5	204.5	148

[1] These figures are to some extent uncertain.

Most of the programmes have a duration of three to five years. The structure of the programme administration differs. The Norwegian Foundation for Scientific and Technological Research (NTNF) is responsible for three programmes. The Research Foundation at the Norwegian Institute of Technology is in charge of three programmes, and various public and semi-public institutions are running the rest.

Except for one programme, IPS, all have been evaluated to some extent. Two different models have been applied. In nine of the twelve programmes the evaluation work has taken the form of either a mid-way investigation identifying the results or a final evaluation of the programme. The evaluation took the form of ". . . an overall judgement about the effectiveness of a programme" [22]. This summative evaluation focused on whether the goals of the programmes were achieved or not. A third model for evaluation, combining action research strategies [30] and formative evaluation, is applied in the BUNT programme [21].

Two of the programmes (ix and xi in Table 1) have been, or will be, evaluated according to the summative model. Eight others (i–vi, viii and xii) had some kind of formative evaluation, even though the formative element was fairly modest. An impact on the programme was expected to result from the written reports.

Addressing the question of what results have been obtained, I will start by reviewing the literature on the programmes that are already finished. These are not encompassed in Table 1. Very few of the finished programmes have actually undergone systematic evaluation. Therefore the conclusions to be drawn from the results will be very fragmented.

Gulowsen and Stenset [31] evaluated one programme. This was operative from 1985 to 1988, and was evaluated for the years 1985 and 1986. The researchers ended up with a fairly critical conclusion that the programme was most effective as an economic aid to small companies, and less important as an instrument for the transfer of technology. In this specific programme consultants worked out a technological assessment of the company. The report concluded that the results depended much on the consultants' competence. A well argumented assessment led to successful use of new technology.

Remø [32] addresses several Norwegian and foreign programmes on technology transfer and focuses his interest mainly on the programme level. A strong recommendation in his report was to integrate companies' investment in new technology into an overall strategic plan. Technology investment must be considered as an element in a total business plan. He also recommends that the programme should have the form of an infrastructure more than a financial source. In another study, Remø [33] assesses five unsuccessful transfer projects. On the basis of this analysis he again pinpoints the importance of a strategic plan for technological investment, and how local competence is a key factor for local company use of new technology. The 'tacit dimension' in the local knowledge is used to explain one of the unsuccessful transfer stories.

The lesson learned from these evaluations is basically the need to integrate the introduction of new technology into an overall strategic plan. A programme should not be a source for economic support. Attention should be paid to the fact that competency is a key factor for local use of new technology. None of the studies explicitly includes an in-depth organizational analysis of the company-based innovation process.

Evaluations of the ongoing projects (the projects listed in Table 1) focus mainly on issues that seem to be critical for the programme's success. Arbo, Gulowsen and Aanesen [34] evaluate the NT programme, and their report focuses on the choices to be made, especially those regarding the programme administration and on what kind of projects the programme should support. Should it support high-risk or low-risk projects? Should the programme concentrate on specific industries or regions, or spread the support over a wide range? In the work done by Levin and Nilssen [35, 36] in evaluating the BUNT programme, five critical factors for success are discussed:

1. What role technology can actually play as a factor in strategic development should be clarified.
2. Attention should be paid to how new technology is introduced in the company.
3. The programme administration should pay great attention to choosing participating companies.
4. Attention should be paid to identifying the characteristics of small and medium sized companies.
5. The consultants should be trained in more than one specific way of working.

A special approach in the BUNT programme has been evaluated by Olsen and Lindø [37]. They focused on a group of four companies networking for improved productivity. This cooperation was organized by a regional consulting group. Their basic focus of interest was on how the programme supported local learning and development. The programme had little effect on the one company with low motivation to participate, while the company with a motivated management benefited from its participation. Fjeldli [37], in a study of the VP programme, indicated a positive effect both on local learning in strategic planning and on company-based internal development.

In an extensive survey and analysis of Norwegian programmes on technology transfer, Torvatn and Rønningsbakk [24] conclude that almost no attempts have been made to measure the economic results of the programmes, even though one of their goals is to identify economic gains. Further, they conclude:

- Small and medium sized companies seldom require help to find new technology, but need help in technology assessment and implementation.
- The programmes ignore the need for organizational development as an integrated element in a technology transfer process.
- Developmental activity has to comply with market demands.
- Participating enterprises are very different in their level of professional operation, and participants in programmes have to be carefully selected.
- Programmes do transfer knowledge and routines.
- Programmes often lack a clear strategy.

Most of the Norwegian programmes on technology transfer have been evaluated. The lack of economic indicators identifying success or failure is evident. The evaluations have, on the other hand, focused on the more qualitative aspects of technology transfer. Basically, the evaluations deal with the process of company development. Why is this so? The answer will have to be found in an in-depth analysis of an actual programme for technology transfer.

The evaluations do not paint a consistent picture of factors for success or failure. None of the evaluations has a clear and consistent model for understanding technology transfer. On the other hand, this fragmented picture identifies the importance of the local developmental process, stating that the results depend on the consultant's work. Introduction of technology should be integrated into an overall strategic business development plan, but the role of technology as such a process is rarely clarified. The most consistent findings are that the success of a technology transfer programme is dependent on company-based developmental processes. The local process can be identified as learning, organizational development, or one depending on the consultant's process skills. Taking these findings seriously, the next step must be a closer investigation of the operational models for Norwegian programmes on technology transfer. Through this analysis it may be possible to present a more consistent picture of what ideal types of process the different programmes lead to. This knowledge will, hopefully, be relevant for knowledge-based decisions on how to design programmes on technology transfer.

6. Norwegian programmes on technology transfer — analysed as a TLD process

In this section the aim is to present and examine transfer programmes in terms of the TLD model. To prepare the ground for this analysis, the characteristics of the programmes are categorized and presented in matrix form as shown in Table 2. The categories in this table are based on the concept of the TLD process. The data are mainly based on the presentation brochures or written material from each programme.

6.1. The programme administration process

Basically, two different models for administrating the programmes have been applied. The traditional model is the *science foundation* process, where the programme is organized as a bureaucratic structure with a board of directors taking care of applications, and an executive with limited credentials responsible for day-to-day operations. The monitoring of the running programme is mostly based on budgetary controls. Any programme that uses the correct amount of money in the expected period operates satisfactorily. Programmes such as SMB-U, FUNN, IPS and MARIN BIOTEK operate according to this principle.

Participation in the programme is decided on the basis of a formal evaluation procedure, while the monitoring function focuses on how the money is spent. The problem with the science foundation model is the lack of follow-up control and the lack of adaptation to changing problems, while its strength is the equality that results from the formal application procedure among the candidate companies.

The other model is the *flexible adaptation* administrative process. These programmes may have a board, but only for issuing general guidelines for the operation of the programme. Much power and operational freedom is given to the programme administrators. Usually the director has a reasonable reputation in both the business world and the political and administrative establishment (BUNT and NSP). A continuous monitoring process is usually combined with the operational freedom of the programme administration. Such programmes will potentially have a greater freedom to adjust to changing conditions, and to correct their operational characteristics according to a systematic and continuous evaluation.

In this model, evaluation is crucial. A high potential for adjustment by the programme administration also demands a reasonable analysis of the programme so as to be able to direct its efforts towards achieving the goals. This evaluation process can fruitfully be done by outside institutions. The integrity of the evaluator versus the programme administration opens up the way to a balanced relationship, which improves the standard of evaluation. The BUNT programme is the clearest example of integrating unbureaucratic and flexible administration with continuous evaluation. This evaluation is done by the programme itself and by outside evaluators. The NSP and DTS programmes are, to a certain extent, in the same category, with a reasonably high degree of freedom for the programme administration. On the other hand, these two programmes have been evaluated only to their midpoint.

A problem that can occur during the flexible adaptation may be that the programme director exerts too much power and shows little openness for contradictory points of view. The strength is the ability to adjust quickly and effectively to changing contingencies.

TABLE 2. Operational characteristics of Norwegian programmes on technology transfer

Programme	Programme administrative process	Mediating process	Technology supplementary interaction	Innovation process
SMB-U	Bureaucratic administration by the bank, formal application procedure, little direct contact with follow-up in companies. Final evaluation	Using a group of selected consultants	Open, no commitments or plans for special connections made	Consultant driven assessment. Funding support for the assessment
NT	Active administration, dealing directly with companies. Actively recruiting companies. Evaluation year by year	Programme leader central in communication with involved companies	Open, no commitments to special sources are made	Joint assessment by outside experts and company employees. Funding from the programme
NSP	Central programme leader with extended credentials. Direct contact with participating companies	Two consultants visiting and assessing companies, with direct applications to administration	Industry specific. Universities and other education institutions. Vendors of equipment also very active	Outside consultant assessment, based on a short visit to the company. Paid for by the programme
FUNN	Administered both by the Science Foundation and the technology supplier. Highly political	Organizations selected by the programme's steering committee	One national vendor	Distribution of hardware to 14 organizations elected by the programme
IPS	Programme leader from Science Foundation. Formal steering committee	Close cooperation with a core group of important companies	Research institutions and universities directly involved with companies in joint research	Dialogue between local production staff and researchers, with possible researcher dominance
DTS	Programme leader located at the Research Foundation at NIT. Mid-point evaluation	Active recruiting by the involved technology attachés. Companies are systematically visited and scanned	Research institutions and universities	Researcher scanning the company and discussing with the local management on potential of relevant new technology
BUNT	Programme administration with extended credentials. Unbureaucratic administrative process. Continuous evaluation	Training of 120+ consultants. Both local and central marketing	All possible sources might be approached	Strategic assessment driven by the outside consultant. 20 days might be used for this work
MARIN BIOTEK	Application procedure in which the board decides on participation. Independent operation of projects	Mediation through announcement in relevant media	Research institutions and universities	Research institutions in dialogue with companies
IDESØK	Programme administration at the Research Foundation at NIT. Evaluation by the operating organization	Active marketing to and involvement of potential companies	Mainly research institutions and universities	Reflection and strategic planning in cooperation with an outside consultant or technological researcher
LOS	—	—	—	—
VP	Programme administered by the Research Foundation at NIT. Steering committee, but relatively high freedom for the programme administration. Evaluation late in operating period by outside organization, with occasional own evaluation	Active marketing to and involvement of shipyards and mechanical companies in northern Norway	Research institutions and universities	Strategic planning done by a group of employees, students and technological researchers. Networking among companies
IND.ATT	Programme coordinated by a semi-permanent organization located in conjunction with the Norwegian Technological Institute in Oslo	Information meetings with potential Norwegian user companies	Technology suppliers in foreign countries, companies, science laboratories and universities	—

6.2. The mediating process

Mediation is identified as the process by which the programme is diffused to the possible candidates for new technology. The most extreme position here is that the 'market' is screened by the programme management. This *vacuuming model* is usually based on thorough knowledge of an industry or region. This is a centralized strategy. Three of the programmes are clearly within this category (NT, VP and NSP). In the NT and NSP programmes the leaders travel extensively, contacting and motivating companies to participate. From this interaction potential candidates will emerge. The aim is to search for the best suited company. The possible advantage of the vacuuming approach is its strong coordination and strict focus on the technology transfer. On the other hand, several risks are taken. Firstly, the decision for participation will be rooted in the opinion of very few people. Their understanding of a company's ability to successfully engage in the programme must be limited simply because of their limited capacity to have an in-depth understanding of the applicant's potential. Secondly, the screening will be rudimentary as it is an almost hopeless task to achieve an overview of all companies in an industry or a region. In small industries and regions it may, on the other hand, be a feasible approach.

Several programmes have no specially designed mediating process. Programmes such as IPS, LOS and MARIN BIOTEK follow a traditional *application model*, where the programme is announced publicly and applications are received and reviewed by the programme management. Competition among the applicants will secure the quality of the programme. Usually no further monitoring takes place, except for checking that grants are used in accordance with public regulations. The strength is, of course, the equality between the applicants created by the formal procedure, but a problem may arise through the lack of flexible adjustment and experimentation in given situations.

The BUNT programme has a fairly special mediating process. The specially trained consultants establish contact with a client company. If an agreement for engagement in the technology transfer project arises, the BUNT programme administration will have the final word. The BUNT mediating system is decentralized while the NT, VP and NSP systems are very centralized. The BUNT programme is also characterized by a very strong and unbureaucratic administration. Operational decisions are taken by a small core group. They have sufficient power and credentials to act independently of the programme board. In a decentralized programme, participation will be based on judgements from 'autonomous' consultants. Viewed in this light, it certainly opens the way for broader participation based on a possible thorough understanding of the individual company's potential. The problem with this approach is the individual consultant's interest in promoting his/her own clients. The consultants will of course earn their money by supporting their own clients. A combination, such as the BUNT model, may be promising.

6.3. Interaction with technology suppliers

One striking fact in most of the programmes is that the sources of new technology are seldom clearly identified. Vendors, research organizations and universities are mentioned, but in vague terms. This may be a consequence of the possible lack of clarification of the 'technology' concept. In a study carried out by Levin and Nilssen [35] it is stressed that in the BUNT programme the technology was not clarified or explained. Analysing other programmes on technology transfer, it appears that technology is rarely discussed. It is taken for granted that technology is the material artefact. The social content and context of technology are very seldom taken into account.

The technology interaction process is a dialogic process in which the primary goal is for the company to discover a potentially profitable use of new technology. I argue, in agreement with Elden and Levin [18], that this is a cogenerative learning process in which the mutual discovery of a smart solution shapes the success. The user participates with knowledge of everyday problems in the company, while the technology supplier is responsible for presenting technological possibilities.

In most of the programmes there is a tendency primarily to link companies with research institutions — the research connection. I will identify this interaction process as the *university link*. This can be explained by different factors. On the Norwegian scene, the research institutions have a dominating position in developing new technology. Few companies have their own research and development laboratories. As a consequence the institutional sector plays an important role in promoting the development of technology.

This can also be seen in an analysis of programmes on technology transfer. Many programmes have been initiated or operated by research or university institutions. Six of the twelve programmes are highly influenced by research institutions, either as key players or as programme administrators. This has an implication for how the interaction with the suppliers is organized. Obviously, the research and university organizations are favoured. Five of the programmes are organized with close links to the research institutions in the technology and supplier interaction process. The link is established mainly by active involvement of researchers in the transfer process. The DTS programme is special because the 'attachés' are former researchers and are responsible for company assessment. On the basis of their experience it is only natural that the interaction process focuses on research institutions. The strength of the university link lies in the professional skills, and in the potential capacity of research institutions to be at the cutting edge of technological development. This can be of special importance in a country dominated by small and medium sized companies. On the other hand, there may be problems in consequence of pushing out to companies technologies that are too advanced and too little in line with what is the best business strategy for the company.

Only two programmes have an *open approach* to all sources of technology. The BUNT and NSP programmes identify all kinds of research institutions and vendors as potential sources for new technology. On the other hand, these programmes rely on the interventionist (consultant, researcher, etc.) as the mediator. It is obvious that the general open approach to the sources of technology, including both knowledge and artefacts, can be misleading. The intermediary will, in this situation, function as a link pin. Firstly, it may not be easy to find relevant technological partners. A consultant may, for instance, have a limited overview of technology sources. Secondly, an intermediary may not have sufficient understanding of the technological possibilities. In both instances the open approach will be problematic, and the cogenerative process will not take place. Either the wrong people will participate, or the participants will have too shallow an understanding of the technological possibilities. The strength of the open approach is the possibility to search for relevant technology after having developed an understanding of what is strategically desirable. If the intention in a technology programme is to support technology transfer on the basis of a proper business strategy, the open approach to technology suppliers is mandatory.

6.4. The innovation process

The crux of the technology transfer programme is the local innovation process. The bottom line for technology transfer is whether the technology has been used to increase the competitive edge of the company. Therefore, the organization's potential to transform impulses, gained through participation in a technology transfer programme, to actual implementation, decides the success. This is identified as the local innovation process. In the model in Fig. 2 I argue for understanding innovation as linked with technology supplier interaction and the acquisition of the technology process. The supplier interaction and acquisition process support the crucial innovation process, and all three should be seen as linked.

In other words, technology transfer programmes should be organized around the desired models for company-based innovation processes. When analysing Norwegian programmes on technology transfer, it is striking how hard it is to find explained and argued models of how to organize this social development process. The BUNT programme argues for the importance of consultants being skilful in processes, but does not explain what this means, or how to train intermediaries [21].

From an analysis of the available data, three different ideal types of process emerge: the leading agent process, the strategic consultant process and the researcher driven process. None of the programmes trained consultants or researchers in process skills. Therefore, only their background and experience of professional work would shape the interaction and thereby the innovation process with the companies.

6.4.1. The leading agent process

Most of the programmes belong to this category. SMB-U, NT and NSP clearly fit in here. The applied innovation model seems to be that one outside person should make an assessment of the company, either by himself or together with his employers. The goal is to scan for possible use of new technology. In this process people in the local company may learn, but they may also be subordinated partners in a skew social relation, where the outsider dominates the arena. The premises will often be provided by the outsider. In reality, the decisions are made by the same person and the local company is the receiver. The strength in the leading agent model is the company's ability to benefit from a skilled person's competence in choosing appropriate technology, while the pitfall is the introduction of technology that is not useful for the company because the employees do not have the necessary skills to operate it, or that the technology is not adjusted to market demands.

6.4.2. The strategic consultant process

This is the BUNT model. The programme has trained 120 consultants in strategic planning and development. Only those consultants who have passed the training programme can work on BUNT supported companies. The basic model for strategic planning and development is scissored from models developed by Harvard Business School [38]. The consultants were well trained in analytical models for strategic assessments, but had little training in process consultation.

The VP programme is, to some extent, similar in focusing on strategic planning, but in this programme the interventionist has passed no training programme. On the other hand the strategic planning process is done in an offsite seminar where both interventionists and employees from a group of companies work together. The strategic consultant process differs from the leading agent process with respect to the business strategic dimension. Therefore, its strength will lie in the decision to introduce new technology based on an overall strategic business plan. The problems are the same as for the leading agent process, namely the introduction of new technology that the receiving company cannot operate effectively. Another problem may arise from the empirical fact that most of the strategic consultants are generalists and do not have in-depth knowledge of the technological possibilities. Accordingly, this lack of in-depth technological know-how may lead to investment in the wrong technology.

6.4.3. The research driven process

The DTS programme is based on the work of former researchers at the research organization at the Norwegian Institute of Technology, engaging in company-based dialogues and assessments. The working model in the programme is to bring experienced technological researchers into a discussion with employers in small and medium sized companies. The researchers initiate this discussion by paying a visit to different companies. New technology will result either directly from this discussion, or as a consequence of a research contract with the research organization. Part of the expenses for this research will be funded by the programme.

The IDESØK programme can be viewed as a

combination of the strategic consultant and research driven models. The programme is based on initiating strategic planning at company level, and trained technological researchers participate in this process. The problem inherent in the research driven process is the researcher's possible overfocusing on what kind of technology it is that has the cutting edge of development. The result may be a misled investment in a technology that is not mature enough to be operated in a small or medium sized company. The strength, on the other hand, is linked to the potential that is inherent in a successful application of front-line technology.

The argument is not whether the leading agent, the strategic consultant or the researchers have a reasonably clear role specifying their obligations in an intervention. Our main argument is that their role does not reflect social developmental activities. This thinking is of course closely related to a metaphor identified by Morgan [40] as the understanding of an organization as a machine. This technocratic view of the organization focuses on structure and formal procedures. Structure and technology are objective realities where shifts in structure and technology are done by changing parts. Taking this position, it is clear that developmental processes have no place. Therefore, the innovation processes can best be characterized by the attitude of *laissez-faire*. Most of the programmes, unfortunately, belong to this category. No attention is paid to the social elements of technology. The BUNT programme accepts the need for local developmental skills among the consultants, but no specific training is given.

7. Technology transfer as viewed by the industrial user

So far the focus has been placed on the system level of the technology transfer programmes. However, it is beyond debate that technology transfer is relevant only if it can support the profitability of the individual companies. In this section the intention is to investigate technology transfer at the company level by presenting examples of industrial use. Examples will be presented of how technology has been transferred and implemented in a selection of SMEs. It seems that the best way of presenting examples from industrial applications is to give a complete and integrated story of a technology transfer process. The data is based on research carried out during evaluation of the BUNT programme [23].

7.1. The fire prevention equipment producer

A Norwegian producer of fire prevention equipment had for some time experienced the problems of being unable to fulfil orders within a reasonable given time. The company needed to improve its production system, and when the BUNT programme became known it applied for it. A former consultant had participated in the BUNT consultant qualification scheme, and he contacted the BUNT programme management. The fire prevention company was accepted and enrolled in the technology transfer programme. The initial work by the consultant was to develop a strategic plan for the company. The learning process started with the work of the consultant. The senior management of the company cooperated with the consultant in developing the strategic plan. Through the consultation process a mutual understanding emerged on the need to invest in new production technology. The consultation process in this technology transfer programme resulted in an investment in a new automated coiled plate sheet-cutter and welding line. Thus a local innovation process started even in the initial stage of the consultant's interaction with the company. The management became acquainted with the possibilities and pitfalls of implementing a new automated production line, and were able to start preparing the organization for the introduction of the new technology. Contact with the technology supplier was undertaken by the consultant, based on the strategic understanding that it was a necessary factor in improving the operation of the production system. In this example we can also identify that the consultant, being a professor at a regional college, was able to use knowledge from university-based research to search for the appropriate technology.

This example shows how a strategic consultant-driven technology transfer process supports a successful technology transfer. The consultant links the company with the transfer programme through the decentralized mediation process. The consultant is also, during the consultation process, very aware of the need to support the local learning and developmental process, and facilitates an efficient local innovation process. In addition the consultant utilizes professional college-based skills in production technology in the search for an appropriate vendor.

7.2. The sports garment producer

This is a small textile producing company located in a small town in Norway. The company has specialized in producing custom designed suits for competition shooters. The lead time for the production was considered to be problematic, as no suit could be finished before the necessary measurements had been made of the potential customer. A technology transfer programme, based at the Norwegian Institute of Technology, involved sending out engineering researchers to scan companies in specific regions. This research had a few meetings with the local management. Through resulting conversations it transpired that the company was looking for technology that could support and improve the production planning and scheduling system. Contact was established with the university, and a specialist in computer-aided production planning began working on the problem. From this work ideas developed to integrate a PC-based system for measurement, to be located at the dealers. The intention was to use the PC to interact with the measurement of the customer and to transmit the data directly to the production facility. On the basis of this technology, the company was able to deliver a finished shooting suit to the market within a total production and transport time of less than one week.

This transfer of technology was based on the 'vacuuming' model for identifying possible candidates. The vacuuming was done by a researcher responsible for relationships between companies and research institutions in the county. The development of the new technological concept was done in the research institution but with reasonable contact with the user company. Some local learning and development took place at the company level, but the project was to a high degree research driven.

7.3. The farm equipment producer

This company produces a wide range of different types of farm and barn equipment. The company was experiencing problems caused by a declining market for farm-related goods. One of the members of the board was also the leader of the community's public-supported consultation agency. He was aware of the emerging BUNT programme. He provided a link to the programme, and a strategic consultant from his organization began working in the company. During the initial strategic consultation process the problems in the production process were visible in many areas. Production had an awkward layout and the material and planning system was inadequate for the complex product spectrum. The strategic consultant worked closely with the new managing director, bringing forth a strategic plan that was well integrated into the director's action plans. The technological development began by rearranging the production layout from a component organization to a product flowline layout. At the same time work started on specifying a new system for material and parts planning. This work was done in cooperation with the same vendor that had delivered the former system. The consultant was hired to help out in this change process, and it seems likely that he supported local learning and innovation processes.

The farm equipment producer was linked to the technology transfer programme (the BUNT programme) through contact with a board member. Later, the strategic consultant took over, and he designed a local learning and developmental process that involved, to a very high degree, the new managing director. Through this interaction a local learning and developmental process was initiated, resulting in the successful use of the new technology, developed both locally and from vendors.

8. Conclusions

Our analysis has resulted in identifying ideal types of variables in a technology transfer programme. Using the initial TLD model, the ideal types are filled in on Fig. 3.

In this presentation, a programme can be designed according to any permutation of these variables. However, this is not just an interesting research finding, even though the result can be as many as 54 (= 2 × 3 × 3 ×3) possible variations. The main point is that identifying that there are possible choices demands a conscious design of a technology transfer programme. Every variable, as presented in this model, has certain characteristics. A conscious design demands that a programme should be created according to what is necessary to be able to reach the desired goals.

From the analysis there is little evidence that the design of Norwegian programmes has seriously taken into account the socio-technical nature of technology transfer. The lack of planned learning and developmental processes is evident. Even where the programmes present models for change processes, they are mechanistic plans for implanting new technology. The problem which then occurs is, of course, that they seldom reflect the organizational challenges in a technology transfer process. The *laissez faire* attitude can best characterize how programmes deal with local company-based change processes.

In a TLD model for technology transfer, the critical success factor is the company-based innovation process. A programme can be effective in all other phases, but no success is reached if the company's innovation process does not evolve as a socio-technical learning and developmental process. None of the reviewed programmes formulates social science based models for visualizing the innovation process. The leading agent, the strategic consultant and the research driven innovation processes can all be significantly improved on the basis of increased training in managing change processes. The point here is not to argue that one model per definition is much better than any other. The core position is to integrate knowledge on how to go about changing organiza-

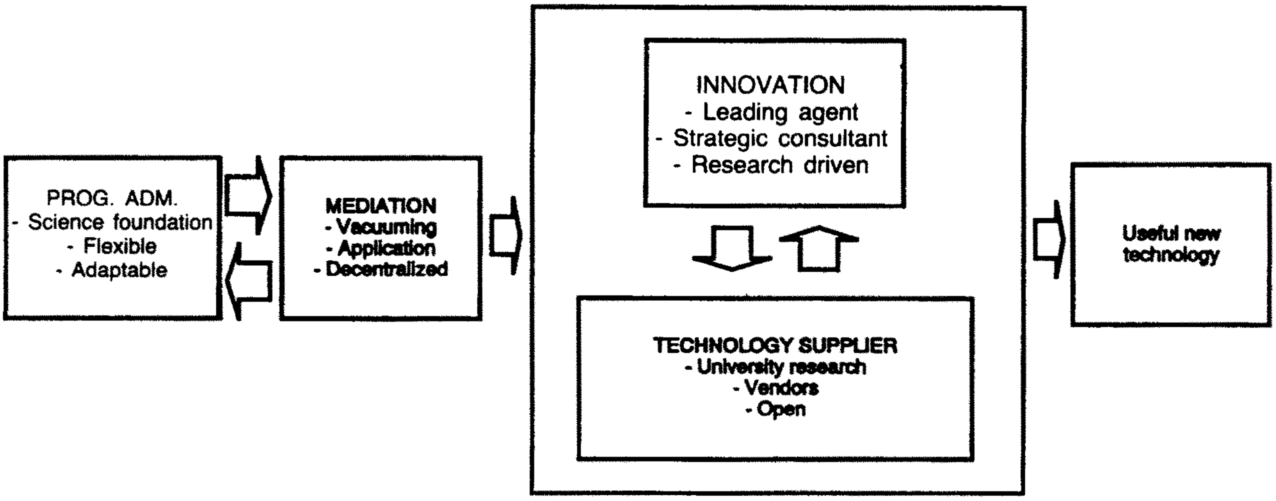

Fig. 3. Ideal types of TLD variables.

tions into all strategies for technology transfer. It is important to consciously choose the relevant model for the innovation process according to the company situation.

A programme for technology transfer, following the arguments developed in this paper, should be administered according to a model for a flexible administration process. A continuous monitoring function, done by independent evaluators, should engage in a continuous dialogue with the programme management, thus securing a mutual learning process at the programme level. Given this flexible administrative structure, the company-based innovation process should be chosen and supported according to the contingencies presented by the actual user/supplier relationship. Accordingly, a programme should be so resourceful that different types of innovation process can be supported. A programme for technology transfer is not a universal entity applicable to every country and every region. Programmes should be designed consciously according to the existing contingencies. The main point is that designers of programmes should be aware of, and understand the implications of, design options.

Firstly, if one accepts the arguments in this paper, a programme on technology transfer should be conceived as a socio-technical-based learning and developmental (TLD) process. The reason for this is that it is important to be aware of the complex nature of technology transfer, encompassing both the movement of technological artefacts and the transfer of knowledge and cultural skills, and aiming at supporting a company-based learning and developmental process. Secondly, a programme should be adjustable to changing conditions and a monitoring function should be closely linked with the programme administration, thus facilitating the continuous learning process within the programme itself. The third and final point is, of course, that every operational characteristic in the mediation, innovation and technology supplier process should be designed according to the actual situation.

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Notes

[1] The official Norwegian definition of a small or medium sized enterprise is one where the number of employees is less than 200. In comparison, the European Community definition indicates less than 500 employees. Only a marginal number of Norwegian companies employ more than 500 persons.

[2] The mutual learning process argued for is parallel to what Elden and Levin [18] identify as cogenerative learning, where actors with different backgrounds interact in a mutual learning situation. The outcome, which is context-bound knowledge, is a shared understanding given that specific situation.

[3] A socio-technical system was originally conceived as a system focusing on the relationship between technology and the social system [39–41]. In their work technology was usually considered as a material artefact, but I add to this dimension the cultural skills embedded in any technological artefact.

[4] We use the term developmental process to indicate large-scale changes spanning beyond individual adaptation. Firstly, technology transfer is an organizational developmental process [42]. Secondly, the literature on organizational development presents theory and concepts on how to go about systematically changing an organization (see for example [43–45]).

[5] The distinction between supplier interaction and acquisition process may sometimes be difficult to identify as the two processes tend to merge. On the other hand, in the conventional sequential model the separation is considered to be clear-cut and it will therefore be reasonable to continue by denoting supplier interaction and acquisition as two different categories.

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APPENDIX: A short description of Norwegian programmes on technology transfer

SMB-U

The programme is administered by the State Bank for Small Business Development. The basic aim is to increase the competence level in production development. The programme uses 35 certified consultants for an initial assessment. Funds can then be available for actual projects that aim at increasing the product developmental process.

NT

This programme has a geographical focus on northern Norway. The aim is to increase the competitiveness of companies in northern Norway through innovation and technology transfer. The process comprises three stages, starting with an idea generation process for business development. The next stage is to support the transfer of technology, and the final stage involves increased cooperation between small and medium sized companies.

NSP

The aim is to increase competitiveness in mechanical industries using welding. Northern Norway should have at least 20% of the available funds, but companies from the whole country can participate. Consultants with special knowledge in welding scanned companies and made recommendations for investment in new welding technology.

FUNN

Fourteen centres have been developed, using computers produced by Norsk Data. The hardware was given free of charge, but each local organization had to be profitable by 1990. Each centre should focus on the local market.

IPS

This programme constitutes the Scientific Foundation's effort to increase the use of CIM, FMS and MPS. It is most suited for larger corporations, and each project within the programme is based on cooperation between companies and research institutions.

DTS

This programme is initiated by the Research Organization at the Norwegian Institute of Technology. The basic aim is to disseminate technology to small and medium sized companies through a process whereby former researchers visit companies in specific regions. Each researcher has his own region to work within. After the initial assessment, support can be granted for research assistance.

BUNT

The aim is to increase the competitiveness among small and medium sized companies in Norway. The basic strategy is to train consultants to make strategic assessments in the companies. This forms the basis for transfer of technology to each company. Companies all over the country can participate.

Marin Biotek

The aim of this programme is to stimulate growth and development in fishing and fish-farming industries through the development of biotechnological methods, and to increase competence in marine biotechnology. The programme is open to a wide range of different companies, which have to apply to the programme administration.

IDESØK

The aim of the programme is to develop a technology strategy in small and medium sized companies in the northern part of Norway. The basic idea is to gather 6 to 8 companies in a joint developmental process. A technological expert will work closely with each company in both strategic planning and technology strategy.

LOS

The programme is funded by the State Developmental Bank. Its aim is to increase the competence of small and medium sized companies. The programme will fund technology projects with a research component and also projects aiming at business development. The participating companies are selected on the basis of their applications, and projects encouraging cooperation are viewed favourably.

VP

The aim of this programme is to increase the competitiveness of mechanical workshops and shipyards in northern Norway. It is based on initiating a strategic planning process, which is done in cooperation between researchers and students at the Norwegian Institute of Technology and local employees. A company will, over a period, have close relations with one researcher.

IND.ATT

The aim is to give Norwegian companies access to international technological development. Norwegian experts are working in several industrialized countries to gather information about technological development. This knowledge is then disseminated to interested Norwegian companies.

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