An Overview of Technology Transfer and Technology Transfer Models

Abstract

In today's business setting, interest in the profitable exploitation of a firm's technological assets, through technology transfer, has intensified. Factors that have facilitated international technology transfer include globalisation of business, liberalisation of the economic regimes of many countries, and the impetus given to the protection of intellectual property after the formation of the World Trade Organization (WTO). These factors have collectively resulted in commercial transfer of technology becoming an important element of the international business setting. Experience over the decades has shown that the technology transfer process can be problematic and transferees often lack the skills to manage it effectively. While the literature is rich in terms of the coverage of the areas of concern it is sparse when it comes to possible approaches that can be taken to remedy these problems. This paper proposes a "Life Cycle Approach for Planning and Implementing a Technology Transfer Project" that could help address some of the important process management problems faced by managers of technology transfer projects and avoid common errors that they tend to make. The paper commences with an overview of technology transfer and some important existing models of technology transfer. The strengths and weaknesses of these models are pointed out and an eclectic model titled, "The Life Cycle Approach for Planning and Implementing a Technology Transfer Project" is presented. It is envisaged that this model could help in addressing many of the common problems that are faced by transferees of technology. The paper concludes with an initiative that the UNESCAP Asian and Pacific Centre for Transfer of Technology (APCTT) is currently developing, based on the Life-Cycle approach, to help technology transfer capacity building in the Asia-Pacific region.

Keywords: Technology transfer, small and medium enterprises, technology transfer models, life-cycle approach, technology transfer problems, technology transfer capacity building

This paper was prepared by Dr. K. Ramanathan, Head of APCTT

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1. INTRODUCTION

Firms have many ways of exploiting their technological assets for profitability and growth. While internal exploitation of technological assets, through designing, developing, manufacturing, and selling products and processes continues to be important, interest in their external exploitation through technology transfer has intensified in recent years. This may be attributed mainly to the globalisation of business, liberalisation of many developing economies, and greater emphasis on the protection of intellectual property after the formation of the World Trade Organisation (WTO). Indeed, today, the transfer of manufacturing technology has become an important part of the international business strategy of firms.

However, the importance of technology transfer from a development perspective is nothing new. More than three decades back, Mansfield (1975) pointed out that, "One of the fundamental processes that influence the economic performance of nations and firms is technology transfer. Economists have long recognized that the transfer of technology is at the heart of the process of economic growth, and that the progress of both developed and developing countries depends on the extent and efficiency of such transfer. In recent years economists have also come to realize (or rediscover) the important effects of international technology transfer on the size and patterns of world trade."

Technology transfer (TT) is an area of interest not just to business, economists, and technologists but also to other disciplines such as anthropology and sociology (Zhao and Reisman, 1992). While anthropologists emphasize the impact of TT on changes in patterns of culture and society, sociologists are more concerned with its role as a vehicle to develop the capacity of individuals and societies to cope with modernization and related changes accompany it. For economists, as argued by Mansfield (1975), the focus is on economic growth and achievement of economic goals. However, from the perspective of business and technologists the main focus of TT is to improve the competitive advantage of firms through the enhancement of customer value (Ramanathan, 2001). It is envisaged that, through the improvement of competitive advantage, a firm and its partners collaborating in the TT will gain financial and other strategic benefits.

Mayer and Blaas (2002) point out that, in recent decades, SMEs have begun to utilize technology transfer as a strategic means of meeting challenges posed by the globalisation of business. Due to their small size and skill resource constraints, they cannot carry out internal R&D to generate their own technologies but still need a flow of new technology to be able to compete. This need has created a new niche-market for technology transfer (Morrissey & Almonacid 2005). The importance of technology transfer, from an economic and competitiveness perspective, has also stimulated university–industry technology transfer. This is evident from the emergence of technology transfer offices in most research offices and universities (Siegel *et al*. 2004). Ramanathan (2000) shows that in today's international business setting, depending on the attributes of the technology, its intended use, and the motivations of the transferee and transferor, a wide range of TT modalities are available. The focus need not merely be on the purchase of plant and equipment or licensing.

However, planning and managing a technology transfer project, especially an international technology transfer (ITT) project, is not easy. Based on the experience gained over three decades, Godkin (1988) provided a comprehensive list of problem areas associated with technology transfer. Many of these problems still persist and with rapidly changing technological and business trends new problems have emerged. The productive entities that have been most affected by these problems are small and medium enterprises (SMEs). While large organizations may be able to gain access to the resources needed to overcome these problems this is usually not the case with SMEs. Evidence exists to show that governments, international agencies, and non-governmental organizations (NGOs) have all attempted to alleviate these problems by introducing various supportive measures. Yet, many of these measures make the tacit assumption that technology transfer (TT) is a relatively predictable process whereby buyers of technology (transferees) acquire, assimilate, and then improve the purchased technology, often with assistance from government policies (Cusumano and Elenkov, 1994). This approach tends to oversimplify the magnitude of the problem faced by SMEs in planning and implementing TT projects.

The main objective of this paper is to draw attention to the problems commonly faced by SMEs in planning and implementing technology transfer and argue that a holistic approach needs to be adopted by SMEs to successfully bring in the technologies they need, through TT projects, so that they can compete effectively and grow in today's global business setting. The rest of this paper is divided into four parts. The next part, which is the second of this paper, presents an overview of technology transfer and suggests that in today's business setting it may have to be viewed with fresh perspectives. This is followed by a review of common TT models that have been developed over the past few decades. Their strengths and weaknesses are described briefly. This is followed by the fourth part of this paper that argues that firms may consider adopting what may be called the "Life Cycle Approach for Planning and Implementing a Technology Transfer Project" to overcome the difficulties and common problems that they face in transferring technology. The fifth and concluding part then presents an initiative being planned by the Asian and Pacific Centre for Transfer of Technology of the United Nations – Economic and Social Commission for the Asia and Pacific (UNESCAP–APCTT) to help SMEs overcome these problems.

2. AN OVERVIEW OF TECHNOLOGY TRANSFER: DEFINITION AND MODES

Interest in technology transfer goes back to over six decades. During the colonial era, technology transfer by colonial powers to production entities in their colonies was mainly in the primary sector such as mining, plantation and agriculture (Ramanathan 1989). Those transfers were aimed at the development of methods and techniques in order to obtain the maximum output in export industries such as mining and plantation agriculture and the development of infrastructure for such industries. After independence, in the late 1940s and early 1950s, many governments in the newly independent countries showed great interest in acquiring technology for import-substitution and often relied heavily on firms from their former colonial rulers to gain access to the technologies needed (Bar-Zakay 1971; Ramanathan 1989). In this era, transfer of technology by multinational companies (MNCs) became common, and public international bodies and not-for-profit organisations also became involved in such activities with the aim of improving living conditions in the recipient country by producing goods to be sold in the local market (Robinson 1988). However, the transfer of technology of MNCs, through foreign direct investment and licensing, became controversial, and considerable literature emerged that was highly critical of their motives and mode of operations (Robinson 1988; Ramanathan 1989; Takii 2004). In fact, technology transfer became so controversial that attempts were made by UNCTAD to develop a "code of conduct" for technology transfer. In recent times great changes have taken place in the global setting. The demise of the former Soviet Union, the emergence of many new CIS nations, the opening up of China and India, the transition of many countries from centrally planned to market-oriented economies, and the privatisation or breaking up of large state-owned enterprises in many developing nations have provided opportunities for international technology transfer to take place on an unprecedented scale (Radosevic 1995, Sadowski 2001).

Definitions of Technology Transfer

Even though technology transfer is not a new business phenomenon, the considerable literature on technology transfer that has emerged over the years agrees that defining technology transfer is difficult due to the complexity of the technology transfer process (Robinson 1988; Spivey *et al.* 1997). The definitions depend on how the user defines technology and in what context (Chen 1996; Bozeman 2000).

The term technology transfer can be defined as the process of movement of technology from one entity to another (Souder *et al.* 1990; Ramanathan 1994). The transfer may be said to be successful if the receiving entity, the transferee, can effectively utilise the technology transferred and eventually assimilate it (Ramanathan, 1994). The movement may involve physical assets, know-how, and technical knowledge (Bozeman, 2000). Technology transfer in some situations may be confined to relocating and exchanging of personnel (Osman-Gani 1999) or the movement of a specific set of capabilities (Lundquist 2003). Technology transfer has also been used to refer to movements of technology from the laboratory to industry, developed to developing countries, or from one application to another domain (Philips 2002). In a very restrictive sense, where technology is considered as information, technology transfer is sometimes defined as the application of information into use (Gibson & Rogers 1994). In a similar vein economists such as Arrow (1969) and Dosi (1988) have analysed technology transfer on the basis of the properties of generic knowledge, focusing particularly on variables that relate to product design. Mittleman and Pasha (1997) have attempted a broader definition where they state that technology transfer is the movement of knowledge, skill, organisation, values and capital from the point of generation to the site of adaptation and application.

It may be useful to examine the distinction between technology transfer and technology diffusion. Sociologists such as Rogers and Shoemaker (1971) and Rogers (2003) have defined technology transfer in the context of diffusion of innovations. This has led to confusion where many researchers, and even practitioners, refer to the terms technology transfer and technology diffusion interchangeably. The literature on technology diffusion, in general, suggests that the term refers to the spreading, often passively within a specific technological population, of technological knowledge related to a specific innovation of interest to that population. Technology transfer, on the other hand, is a proactive process to disseminate or acquire knowledge, experience and related artefacts (Hameri 1996). Furthermore, it is intentional and goal-oriented but not a free process (Autio and Laamanen 1995). Transfer also presupposes agreement and therefore involves agreement, unlike diffusion (Ramanathan 1991; Hameri 1996).

The work of Hayami and Ruttan (1971) and Mansfield (1975) provide some of the earliest insights on the modes of technology transfer which are of relevance even today. Mansfield (1975) classified technology transfer into vertical and horizontal technology transfer. Vertical transfer refers to transfer of technology from basic research to applied research to development and then to production respectively and horizontal technology transfer refers to the movement and use of technology used in one place, organisation, or context to another place, organisation, or context. Souder (1987) refers to the former as internal technology transfer and the latter as external technology transfer. Souder further elaborates upon vertical technology transfer as a managerial process of passing a technology from one phase of its life cycle to another. This elaboration is valuable because it serves to reinforce the fact that it may be possible to horizontally transfer technology at any stage of the technology life cycle. Hayami and Ruttan (1971) and Mansfield (1975) refer to "material transfer, design transfer, and capacity transfer." Material transfer refers to the transfer of a new material or product while design transfer corresponds to the transfer of designs and blueprints that can facilitate the manufacturing of the material or product by the transferee. Capacity transfer involves the transfer of know-why and know-how to adapt, and modify the material or product to suit various requirements. While Hayami and Ruttan focused on agricultural technology transfer, Mansfield emphasised manufacturing technology.

Modes and Mechanisms of Technology Transfer

The above technology transfer concepts were put in perspective by Amsden (1989) and Habibie (1990). Amsden (1989) argued that while in developed countries the technology/product cycle took the route,

{Research to Development to Design to Production}
whereas in technologically less advanced developing countries, it tends to take the route, {Production to Design to Development to Research}.

According to Amsden, learners do not innovate and must compete initially on the basis of low wages, state support, high quality and productivity. The route that must thus be pursued should be based on transfer, absorption, and adaptation of existing technology. This viewpoint fits in with the material, design, and capacity transfer progression. Habibie (1990), often referred to as the architect of the Indonesian aircraft industry, states that, "technology receivers must be prepared to implement manufacturing plans on a step-by-step basis, with the ultimate objective of eventually matching the added-value percentage obtained by the technology transferring firm." He refers to such an approach as "progressive manufacturing" and popularised the slogan, "begin at the end and end at the beginning" implying that a transferee firm should start with production and move backwards to research as also pointed out by Amsden.

Steenhuis (2000) has combined these ideas and developed the concept of "the technology building." The technology building has two wings; the innovation wing consisting of the research, development, production, and distribution stages of the transferor; and the exnovation wing that consists of the distribution, production, development, and research stages of the transferee. The innovation and exnovation wings refer to the technology development stages of the transferor and transferee respectively in accordance with the Amsden and Habibie models of technology development. Steenhuis points out that transfer of technology can take place between the stages of both wings of the technology building in a variety of combinations. The terms innovation and exnovation, as used by Steenhuis, while useful, may cause confusion to practitioners since the term innovation is used in many different contexts. Thus, in this paper the technology development stages of the transferor and transferee will be referred to as "technology generation" and "technology assimilation" respectively.

To avoid looking at technology transfer in a restrictive manner it may thus be useful to view technology transfer possibilities between the "generation" and "assimilation" processes of the transferor and transferee (Ramanathan, 2000). This is shown schematically in Figure 1.

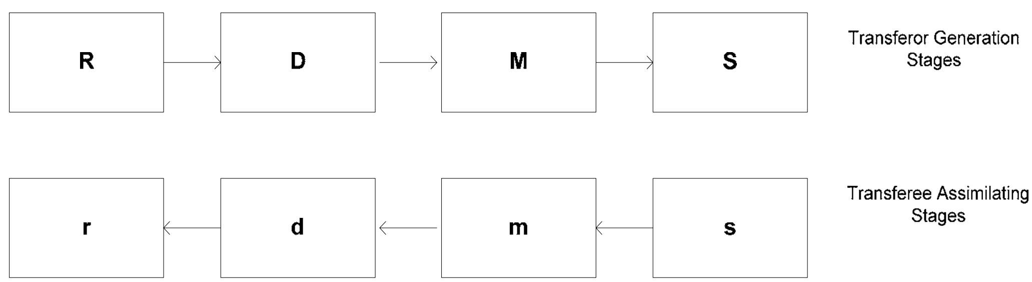


Figure 1. The technology development chains of the transferor and transferee

Using the "technology development chain" concept outlined in Figure 1 above, Ramanathan (2000) points out that the simplest form of technology transfer could be said to take place when an owner of technology (the transferor) transfers the technology needed by a business partner (the transferee) to sell and service a product produced by the owner. This may be depicted as an [S: s] mode of transfer. The representation within parentheses implies that a product at the end of the "generation" stage is simply being sold and serviced by the transferee. The technology likely to be transferred here is that needed by the transferee to sell, repair, and provide other elements of after-sales service to customers buying the product. The objective of the transfer is to effectively maximise the sales of the product in the region managed by the business partner. Another possible variation is [M: s] if the transferee is the sole distributor of the product made by the transferor. These two types of technology transfer arrangements with a predominantly sales focus may be referred to as a "sales intensive mode" of technology transfer.

Based on similar considerations of business objectives, Ramanathan (2001) provides a classification of possible modes and possible transfer mechanisms that may be used. These are summarized below.

Table 1. A Possible Taxonomy of Technology Transfer Modes

Transfer Mode	Possible Transfer Mechanisms
<u>Sales Intensive</u> [S: s] or [M: s]	Sales and service agreement either as an agent or sole distributor
<u>Manufacturing Intensive</u> [M: m,S] or [M: m,s] or [D:m,S] or [D:m,s]	Subcontracting arrangements, original manufacturing arrangements (OEM), production licensing, and joint ventures

<u>Development Intensive</u> [R:d,M,S]or [R:d,m,S] or [R;d,m,s]	Original design manufacturing (ODM), production licensing, joint ventures
<u>Research Intensive</u> [R:r,D,M,S] [R:r,d,M,S] [R;r,d,m,S] [R: r,d,m,s]	Joint R&D and production, university – industry licensing, Government R&D institute – industry licensing

Source: Adapted from Ramanathan (2001)

The term "mode" is used to refer to the transfer links between the phases of the technology development chains of the transferor and transferee while the term "mechanism" is used to describe popular business arrangements that are deployed to transfer technology. The classification does not include the transfer of technology by multinationals to their wholly-owned subsidiaries operating in other locations. The classification proposes that technology transfer arrangements be examined under four main groups namely: sales intensive; manufacturing intensive; development intensive; and research intensive. Each of these categories involve different strategic issues from a business perspective

Based on the above discussion, the following conclusions may be drawn:

- Commercial technology transfer may be defined as a mutually agreed upon, intentional, goal-oriented, and proactive process by which technology flows from an entity that owns the technology (the transferor) to an entity seeking the technology (the transferee). The transfer involves cost and expenditure that is negotiated and agreed upon by the transferee and transferor. The transfer may be said to be successful if the transferee can successfully utilise the technology for business gains and eventually assimilate it.
- Technology transfer can be vertical or horizontal technology transfer. Vertical transfer refers to transfer of technology from basic research to applied research, development, and production respectively and horizontal technology transfer refers to the movement and use of technology used in one place, organisation, or context to another place, organisation, or context.
- In today's globalised and liberalised business setting, many technology transfer modes could be deployed depending on how the technology development chains of the transferor and transferee are linked. Technology transfer can commence from a simple level to a much more comprehensive one with time. The mode chosen would depend on the corporate strategies of the transferor and transferee and the technological capability of the transferee.

The next part will examine some of the popular models of technology transferor that have been developed over the years to help transferees and transferors of technology understand the technology transfer process better.

3. POPULAR TECHNOLOGY TRANSFER MODELS

Since the early 1970s, considering the difficulties and complexities faced by managers of technology transfer projects, researchers, consultants, and practitioners of technology transfer have been proposing models of technology transfer that could facilitate the effective planning and implementation of technology transfer projects. Both qualitative and quantitative models have been proposed. Jagoda (2007) points out that, "Qualitative models often have as their objective the delineation of activities involved in managing TT and the elicitation of factors and issues that can influence the success and/or effectiveness of TT. Quantitative models, on the other hand, aim at quantifying parameters of significance in TT and analysing them with a view towards minimising goal incompatibility between the transferors and transferees of technology.” In this paper, emphasis will be on the qualitative models. The mathematics involved in the quantitative models will not be elaborated upon and only their major findings will be presented.

A Brief Overview of Some Qualitative TT Models

(a) The Bar-Zakay Model: Bar-Zakay (1971) developed a rather comprehensive TT model based on a project management approach. He divided the TT process into the Search, Adaptation, Implementation, and Maintenance stages. He depicted the activities, milestones, and decision points (go or no-go) in each of these stages as shown in Figure 2. The upper half of the figure delineates the activities and requirements of the transferor (referred to as the “donor” by Bar-Zakay) and the lower half that of the transferee or the “recipient.” The activities to be carried out are specified in detail in this model and the importance of both the transferor and transferee acquiring skills to undertake technological forecasting, long-range planning, and gathering of project-related intelligence is emphasised. The model uses the term “donor” for the transferor giving the impression that the owner of technology is giving away a valuable asset out of altruistic reasons! This is clearly not the case and the use of such terms must be avoided.

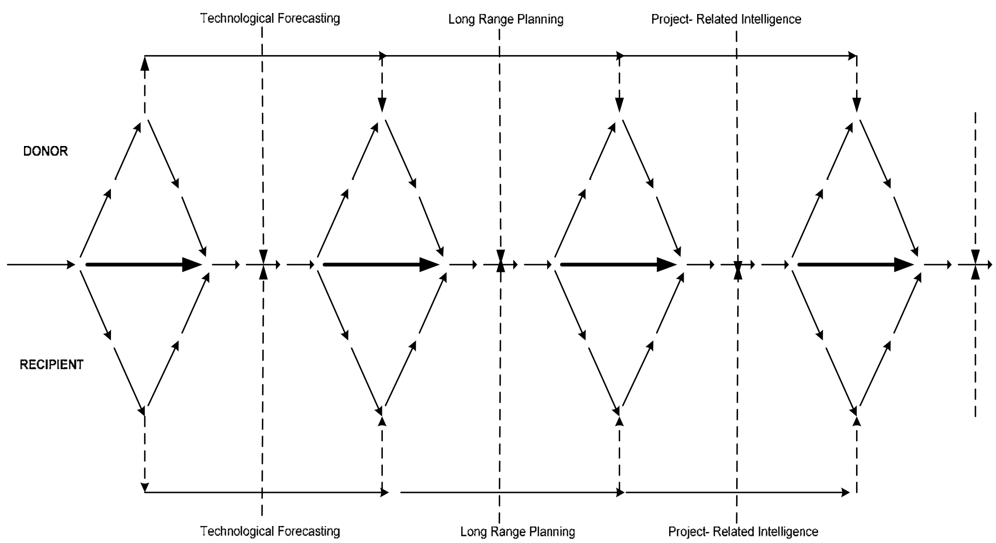


Figure 2. The Bar-Zakay model of technology transfer

Source: Jagoda (2007)

The Bar-Zakay model also suffers from another disadvantage. Jagoda (2007) points out that, “The model has limited relevance today since many of the activities, terms, and ideas expressed reflected the setting of the late 1960s to early 1970s, when buyers of technology were mainly passive recipients who depended greatly on aid programs for the purchase of technology. It was also an era when government controls were instrumental in determining the rate, direction, and scope of technology flows.”

The lessons that can be learnt from the Bar-Zakay model are the following:

- There is a need for a comprehensive examination of the entire TT process from “search” right through to “post-implementation” activities.
- A process approach must be adopted in planning and implementing TT projects
- It is important to have milestones and decision points so that activities can be strengthened, mistakes corrected, or even the project terminated at any point in time.

(b) The Behrman and Wallender Model: Behrman and Wallender (1976) have proposed a seven stage-process for international technology transfer that may be more relevant to multinational corporations. The seven stages are:

- Manufacturing proposal and planning to arrive at decisions regarding location and preparing a business case including good resource assessments.
- Deciding the product design technologies to be transferred.
- Specifying details of the plant to be designed to produce the product and other aspects related to construction and infrastructure development.
- Plant construction and production start-up.
- Adapting the process and product if needed and strengthening production systems to suit local conditions.
- Improving the product technology transferred using local skills.
- Providing external support to strengthen the relationship between the transferor and transferee.

One of the weaknesses of this model is that, during the first three stages, the transferor develops the technology transfer project with minimal involvement of the transferee thereby reinforcing dependency. However, in the fifth and sixth stages there is considerable scope for the transferee to assimilate and improve both product and process technology. This serves to emphasise the fact that technology transfer does not stop with commencement of production and unless there is a mechanism to foster assimilation the project cannot be considered to have delivered.

The lessons that can be learnt from this model are the following:

- There is a need for the transferee to be involved right from the beginning in the planning and implementation of a TT project.
- A technology transfer project does not end with commencement of production.
- Unless explicit measures are in place to ensure assimilation of the transferred technology, the technology transfer cannot be said to have been successful.

(c) The Dahlman and Westphal Model: Dahlman and Westphal (1981) carried out considerable work in the Republic of Korea and, based on their experience in rapidly industrialising countries during the 1980s, in the Far East, have proposed a nine stage process model as follows:

- Carry out pre-investment feasibility to gather information and carry out a techno-economic analysis to establish project viability.
- Carry out a preliminary identification of technologies needed, based on the feasibility study.
- Carry out basic engineering studies that involve the preparation of process flow diagrams, layouts, material and energy balances and other design specifications of the plant and machinery and the core technology to be transferred.
- Carry out a detailed engineering study that involve the preparation of a detailed civil engineering plan for the facility, including construction and installation specifications and identification of the peripheral technology needed to make the transfer effective.
- Carry out the selection of suppliers for equipment and subcontracting services to assemble the plant and machinery and plan for the co-ordination of the work among various parties
- Prepare and execute a training and education plan, in consultation with the suppliers of technology, for the workers who would be employed in the technology transfer project.
- Construct the plant.
- Commence operations.
- Develop trouble-shooting skills and put in place arrangements to solve design and operational problems as they arise, especially during the early years of operation.

This model may be regarded as an improvement of the Behrman and Wallender model with great emphasis on transferee involvement at all stages of the TT project. Its major weakness is that it assumes that the transferee will have access to high-level engineering skills. This may not be true in many developing countries. It also pays very little attention to negotiation and post-implementation assimilation initiatives.

The important lessons that this model presents include the following:

- A TT project is best studied using a sequential process perspective.
- Any TT project should not be commenced without a careful feasibility study since such projects often require heavy resource commitments.
- The transferee should be involved in the planning right from the beginning.
- It is important for transferees to develop sound engineering and project management skills without which the TT process cannot be managed effectively.

(d) The Schlie, Radnor, and Wad Model: Schlie *et al. (*1987) propose a simple, generic model that delineates seven elements that can influence the planning, implementation, and eventual success of any TT project. These seven elements are listed below.

- The transferor, which is the entity selling the technology to the recipient.
- The transferee, which is the entity buying the technology.
- The technology that is being transferred.
- The transfer mechanism that has been chosen to transfer the chosen technology.
- The transferor environment which is the immediate set of conditions, in which the transferor is operating. Attributes of the transferor environment that can influence the effectiveness of the transfer process include, among others, economic status, business orientation (inward versus outward), stability, attitude and commitment to the transfer project, and operating policies.
- The transferee environment which is the immediate set of conditions under which the transferee is operating. Attributes of the transferee environment that can influence the absorptive capacity of the transferee include physical and organisational infrastructure, skills availability, attitude and commitment to the transfer project, technological status, business orientation (inward versus outward), economic status, and stability.
- The greater environment which is that surrounding both the transferor and the transferee. There may be layers of this environment that are sub-regional, regional, and global. Even if the immediate operating environments of the transferor and the transferee are favourable to the technology transfer, if the layers of the greater environment are not supportive, then cross-border and international technology transfer could be adversely affected. Factors in the greater environment such as political relationships between countries, exchange rates, investment climates, trade negotiations, balance of trade, relative technological levels, and the status of intellectual property protection regimes could have a great influence on the success of a TT project.

The seven elements of this model are valid even in today's business setting. The way that they manifest themselves can however change with time. The weakness of this model is that it offers no guidelines as to what a transferee should do.

The valuable lessons that emerge from this model are as follows:

- The many changes that have taken place and are taking place in the global business setting today have made it imperative for managers of technology to gain good insights into the transferee environment, transferor environment, and the greater environment when planning and implementing a TT project.
- The choice of the technology transfer mechanism should be based on a sophisticated understanding of the other six elements.

(e) The Chantramonklasri Model: The Dahlman and Westphal Model has been further improved by Chantramonklasri (1990 who proposes a five phase model as shown in Figure 3.

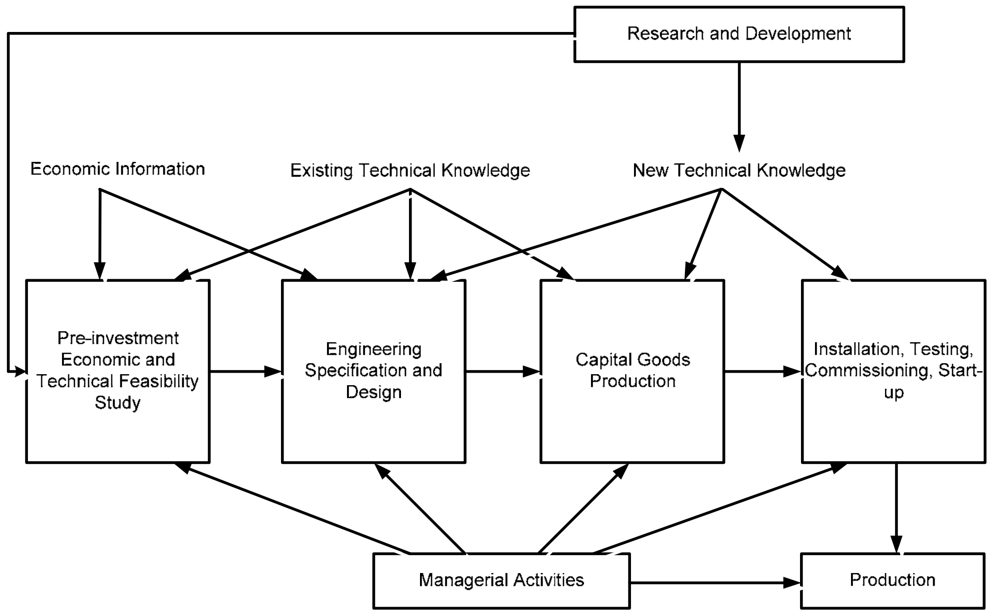


Figure 3. The Five-phase model of international technology transfer

Source: Jagoda (2007)

The five phases of this model are as follows:

- Carrying out a pre-investment and feasibility study
- Developing engineering specifications and design based on the feasibility study
- Commence capital goods production based on the engineering specifications and designs that have been developed.
- Commissioning and start-u including comprehensive of the workforce
- Commence commercial production

While the first two phases of this model are valid it is not clear whether the required capital goods can be produced within the transferee setting unless the transfer arrangement also includes the transfer of technology needed to manufacture these. While this may be valid in large, technologically advanced countries such as China and India, it may not be so in other smaller developing countries. As in the Dahlman and Westphal Model the negotiation and assimilation elements are missing. The lessons that may be learnt in this case are similar to those of the Dahlman and Westphal Model.

(f) Other Qualitative Models of Technology Transfer: There are several other models that have been developed. However, due to limitations of space these will only be described briefly.

Lee *et al.* (1988) have developed a longitudinal model of technology transfer based on a study of developing and rapidly industrialising countries. They point out that a transferee firm needs to put in place strategies to be able to go through the stages of acquisition, assimilation, and eventual improvement. As the firm advances technologically, it needs to choose appropriate mechanisms of transfer, depending on the stage of the life cycle of the technology and their own technological capability profile. They also note that the mechanisms chosen by the transferor to transfer technology will depend on the relative newness of the technology, its strategic importance to the transferor firm, and the level of intellectual property protection needed.

Reddy and Zhao (1990), in a model similar to that of Schlie *et al.* (1987) state that any international technology transfer (ITT) project should examine three main components, which they refer to as the home-country component, host-country component, and transaction component. The home country is that of the transferor and the host country is that of the transferee. The home-country component involves an examination of issues such as home-country government policies on technology transfer (restrictions etc.), the role and strategy of transferring firms from a foreign direct investment point of view, the nature and importance of technology to be transferred, and the firm's global R&D investment strategy. The host-country component involves issues such as host-country government policies related to foreign investment and technology transfer, the relative suitability of the technology being considered for transfer, the technological capability of the transferee and the scope for upgrading, mechanisms of transfer being considered, and the scope for assimilation of the transferred technology. The transaction component consists of important business issues such as the pricing of technology, intellectual property protection, payment modalities, potential conflicts, and measures for ensuring effective transfer.

Keller and Chinta (1990) argue that effective technology transfer would be determined by the extent to which the transferor and transferee manage the barriers that impede transfer and strengthen initiatives that facilitate it. The facilitating initiatives refer to the willingness of the partners to adapt their respective strategic and operational postures to ensure a "win-win" outcome. The barriers could be political, legal, social, cultural, economic, and technological. They also stress the importance of selecting the correct mechanism to transfer the technology.

The UNIDO (1996) model, in what appears to be an endorsement of the Bar-Zakay approach, suggests that, in the manufacturing sector, once the need for a TT project is established, the steps of search, evaluation, negotiation, contract execution, and technology adaptation and absorption should be followed sequentially to ensure effectiveness.

Durrani *et al.* (1998) have proposed a generic model consisting of five steps:

- Establishing market-place requirements
- Identifying technology solutions
- Classifying the identified technology solutions
- Establishing sources from where the desired technology could be acquired
- Finalising the technology-acquisition decision

This model stops with the technology acquisition decision. Its major lesson is that it stresses the importance of establishing the need for a technology transfer project and the need for identifying multiple sources of technology for enabling a better choice of transferor.

Bozeman (2000) has proposed a contingent effectiveness model of technology transfer. While the emphasis is on technology transfer from universities and government laboratories to industry, the model is also relevant to inter-firm technology transfer. In this model, the key elements of the transfer process are:

- The transfer agent (the transferor)
- The transfer mechanism
- The transfer object (the content and form of the technology being transferred)
- The transfer recipient (the transferee)
- The demand environment (market and non-market factors vis-à-vis the need for the technology).

This model also stresses importance of establishing the need for a technology transfer project and the need for identifying multiple sources of technology for enabling a better choice of transferor. Six "out-the-door" measures are proposed. These are market impact, economic development, political benefits, opportunity costs, and development of scientific and human capital as a result of the transfer. The importance of impact assessment is a valuable lesson that this model imparts.

(g) A Brief Overview of Some Quantitative TT Models: The literature is sparse when it comes to quantitative models of technology transfer. Some of the more important models are described briefly. For the sake of brevity, the mathematics has been left out and the interested reader may wish to refer to the original publications.

Perhaps, the earliest quantitative model is due to Sharif and Haq (1980). This model proposes the concept of potential technological distance (PTD) between a transferor and transferee and argues that when the PTD is either too great or too small between the transferor and transferee, the effectiveness of the transfer is low. It suggests that when a transferee first looks for a potential transferor it is important to look for one with an "optimal" PTD. From a practical point of view, a potential transferor at the firm level may not be willing to easily divulge information that could enable an assessment of the PTD. The greatest value of the model is that it draws attention to the need for incorporating the concept of a PTD in deciding the transferor.

Raz *et al.* (1983) have presented a model of technological "catch-up" that shows how a technology leader, through technology transfer, can assist the rate of technological development of a technology follower. The model examines three phases of growth of a technology follower namely, the slow initial phase with high technological capability gap, the faster learning phase with the decreasing gap, and catch-up phase when the technological gap is very small or closed. They argues that this type of analysis would enable technology leaders to develop clear policies, based on considerations of competitiveness, security, and other related issues, when entering into technology transfer agreements.

Using an econometric model, Klein and Lim (1997) have studied the technology gap between the general machinery and electrical and electronic industries of Korea and Japan. Their findings suggest that technology transfer from leaders can play a critical role in upgrading the technological levels of follower firms. Their study also shows that the followers should supplement the transfer by independently putting in place measures to assimilate, modify, and localise the technology transferred from the leader. This model thus emphasises, based on empirical evidence, the need for post-implementation activities that facilitate assimilation and modification of the transferred technology. It also clearly delineates the need for a firm, as it grows technologically, to link its technology transfer activities with internal R&D.

It may be said that the main contribution of the quantitative models is their emphasis on the need for partners in technology transfer projects to develop skills to be able to use formal, analytical approaches that can generate needed information for better technology transfer planning.

An examination of the models of technology transfer shows that there are several valuable lessons that they convey. These are summarized below.

- It is important to expend comprehensive analytical effort in establishing the need for a technology transfer project prior to the commencement of a TT project.
- A TT project should not be commenced without a careful feasibility study since such projects often require heavy resource commitments.
- A process approach must be adopted in planning and implementing TT projects and to ensure effective technology transfer there is a need to comprehensively examine the entire process from "technology search" right through to "post-implementation" activities.
- The many changes that have taken place and are taking place in the global business setting today have made it imperative for managers of technology to gain good insights into the transferee environment, transferor environment, and the greater environment when planning and implementing a TT project.
- Multiple sources of technology must be identified to enable a good choice of transferor.
- The transferee must be involved right from the beginning in the planning and implementation of a TT project.

- It is important for transferees to develop sound engineering and project management skills without which the technology transfer process cannot be managed effectively.
- Partners in TT projects need to develop skills to be able to use formal, analytical approaches that can generate needed information for better technology transfer planning.
- It is important to have milestones and decision points so that activities can be strengthened, mistakes corrected, or even the project terminated at any point in time.
- The mechanisms chosen by a transferor to transfer technology will depend on the transferor and transferee setting, the technological capability of the transferee, the relative newness of the technology, its strategic importance to the transferor firm, and the level of intellectual property protection needed.
- As a transferee firm advances technologically, it needs to choose appropriate mechanisms of transfer, depending on the stage of the life cycle of the technology and its own technological capability profile.
- A technology transfer project does not end with commencement of production. Unless explicit measures are in place to ensure assimilation of the transferred technology the technology transfer cannot be said to have been successful.
- The success of a technology transfer project would be determined by the extent to which the transferor and transferee manage the barriers that impede transfer and strengthen initiatives that facilitate it.

However, what may also be noted is that there is no model that tries to capture all of these important considerations. An eclectic model that presents all this wisdom in a process-oriented approach would be very useful to managers of technology transfer project. Such a model must also have the capacity to address many of the problems faced by firms, especially small and medium enterprises (SMEs), when planning and implementing technology transfer. The next part will first present a summary of common problems faced by SMEs in planning and implementing technology transfer and then propose an eclectic, process model called, “the Life-cycle Approach for Planning and Implementing Technology Transfer” that tries to incorporate the wisdom of the models discussed. It is envisaged that the adoption of this process model will enable SMEs to manage the common problems they face in planning and implementing TT projects.

4. THE LIFE CYCLE APPROACH FOR PLANNING AND IMPLEMENTING A TECHNOLOGY TRANSFER PROJECT

This part commences with a brief presentation of common technology transfer problems faced by SMEs. This will be followed by the “Life Cycle Approach for Planning and Implementing a Technology Transfer Project.”

Technology Transfer Problems Commonly Faced by SMEs

Based on the work of Jagoda (2007) and Ramanathan (2007), problems faced by SMEs in planning and managing technology transfer may be classified into three categories namely, technology transfer process issues, corporate capability issues, and operating environment and NIS issues. The problems are summarized below.

(a) Technology Transfer Process Issues

Problems during the technology justification and selection stage

- Wrong selection of technology based on misjudgements when preparing a business case for a TT project
- The cost of buying, installing, operating, and maintaining the technology is too high
- The technology selected is too complex for easy understanding and assimilation of the transferee
- The technology needs considerable adaptation to suit local conditions
- Obsolescence of technology while the transfer is in progress

Problems during the planning stage

- Transferor (seller) underestimates the problems in transferring the technology to a developing country setting
- Transferor does not fully understand transferee needs
- Transferee managers are not involved in the planning which is carried out only by the transferor
- Too much attention is paid to the hardware to be purchased and not enough attention is paid to skills and information acquisition
- Overestimation of the technological capabilities of the transferee by the transferor thereby leading to unrealistic expectations on how well the transferee can meet target dates
- Poor market demand forecasting by the transferee of the outputs to be produced by using the transferred technology
- The objectives of the transferor and transferee are not compatible
- Mechanisms chosen for implementing the transfer are not appropriate

Problems during negotiations

- Differences in negotiation approaches and strategies
- Lack of trust between the transferor and transferee
- Goal incompatibility during negotiations
- Inability to reach agreements on pricing, product, and marketing strategies
- Both parties try to achieve results in an unrealistically short period of time

Problems during technology transfer implementation

- Shortage of experienced technology transfer managers
- Lack of trust in transferor developed systems by the transferee
- Inability to achieve quality targets
- Delay in obtaining supplementary materials, needed for quick implementation, from the local environment
- High cost and poor quality of locally available materials needed to implement the technology transferred
- Inadequate tracking of the technology during implementation
- Cost overrun due to poor implementation

(b) Corporate Capability Issues

Problems due to inadequate skills

- Inability of the transferee to attract the required skills due to financial and industrial restrictions
- Lack of experience of the transferee's workforce and absence of required skills at the industry level
- Lack of training of transferee personnel
- Absence of incentive systems at the transferee firm for learning and assimilating new technologies
- Language barriers that inhibit effective communication between transferor and transferee personnel and restrict effective transmission and assimilation of relevant information

Problems due to ineffective management

- Lack of visible and committed top management support for the project
- Lack of top management guidance to decide the type of the technology to be acquired, remuneration, incentives associated with the transfer, and the control of the flow of information.
- Differences in working methods and practices between the transferor and transferee managers

- Individual or organisational competition for the ownership of the technologies and the presence of the “not-invented-here” syndrome
- Failure of top management to identify transferee and transferor personnel who would work closely form project initiation through to full implementation

(c) Operating Environment and National Innovation System (NIS) Issues

- Shrinking of local markets due to adverse changes in the economic levels of the country
- Poor physical infrastructure
- Inadequate supportive institutional infrastructure to provide support in terms of finance, information, skill development, and technology brokering
- Inadequate mechanisms for intellectual property protection
- Lack of local suppliers who can deliver quality supplies and lack of policies to develop such suppliers
- High dependency on foreign suppliers and imports
- Lack of good education and training institutions to upgrade skills
- Ineffective legislation and incentives such as tax holidays, tariff adjustments, and industry parks to promote technology transfer
- Bureaucratic delays at various levels of government in obtaining approvals and clearances for finalizing technology transfer agreements
- Ineffective and sometimes excessive government intervention and regulation
- Foreign exchange restrictions
- Inability of new ventures to compete with former monopolies, often owned by government
- Uncertain tax environments

These problems continue to affect SMEs and even large firms in many developing nations. While a SME may not be able to handle problems related to the operating environment and the NIS, it should nevertheless guard against these while working with the relevant Business Associations and Chambers of Commerce to lobby governments to rectify these.

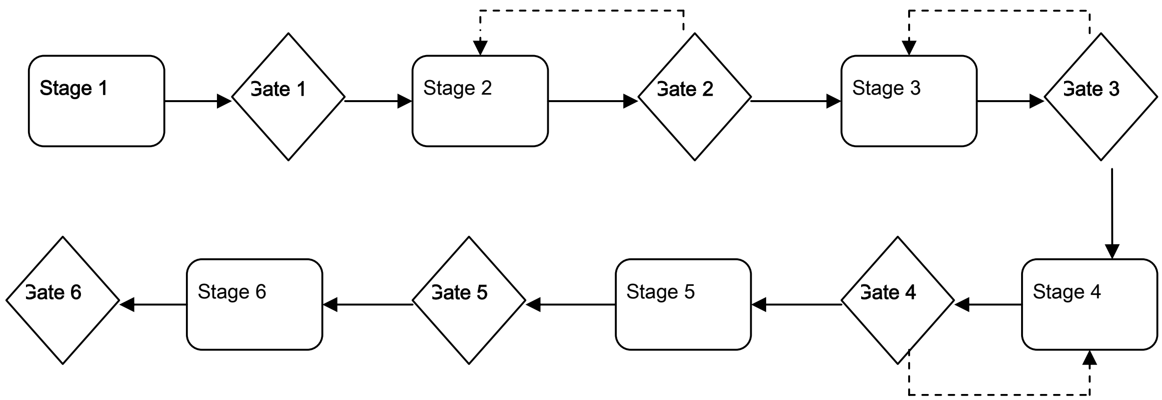
Life Cycle Approach for Planning and Implementing a Technology Transfer Project

The “Life Cycle Approach for Planning and Implementing a Technology Transfer Project” is based on the stage-gate structure developed by Jagoda and Ramanathan (2005) for developing a systematic approach for planning and managing ITT. For the sake of convenience and expository ease, henceforth this model will be referred to as the TTLC (Technology Transfer Life Cycle) approach.

The TTLC approach takes a holistic view of a TT project from its “conception” right up to its “conclusion” and is based on the recognition of the fact that a life cycle of a TT project can be looked at from a process perspective as consisting of six major stages as follows.

- Identifying the technology needed and making a business case to obtain corporate approval
- Searching for possible technology sources and assessing offers
- Negotiating with short-listed suppliers and finalizing the deal
- Preparing a TT implementation plan
- Implementing and assimilating
- Assessing the impact of the TT project

This life cycle has been developed based on the lessons learnt from the study of popular models of technology transfer that have been reviewed in the previous section of this paper. The major stages in the life cycle are shown schematically in Figure 4. It can be seen that, in this generic framework, each stage is associated with a gate. The stages are made up of prescribed tasks with cross-functional and simultaneous activities. The gate or controlling point is at the entrance to each stage. Using the information generated at each stage, in-depth and critical evaluation is carried out at the gate that follows the stage. Based on the evaluation, a decision may be taken to go forward, kill the project, put it on hold, or recycle it. It is envisaged that, through this approach, proactive measures could be taken to avoid or minimize problems thereby enhancing the chances of successful TT. The main advantage of such an approach is that it could ensure that major activities are not carried out carelessly or even missed.



Stage 1: Identifying CVD enhancing technologies	Gate 1: Confirming identified technologies
Stage 2: Focused technology search	Gate 2: Technology and supplier selection
Stage 3: Negotiation	Gate 3: Finalising and approving the TT agreement
Stage 4: Preparing a TT project implementation plan	Gate 4: Approving the implementation plan
Stage 5: Implementing technology transfer	Gate 5: Implementation audit
Stage 6: Technology transfer impact assessment	Gate 6: Developing guidelines for a new project

Figure 4. The Life Cycle Approach for Planning and Implementing Technology Transfer

Stage 1: Identifying CVD Enhancing Technologies

All enterprises whether they are large firms or SMEs can compete effectively only on the basis of “customer value creation.” Customer value may be defined as a function of quality, delivery, flexibility, convenience, and cost (Ramanathan, 2001). Quality represents how well a specific good or service meets customer expectations. Speed describes the time needed to design, produce, and deliver the good or service as characterized by determinants such as cycle time and speed to market. Flexibility reflects how easily and quickly the firm can modify goods or services to meet customer needs in terms of aspects such as options and extent of customisation possible. Creating convenience for the customer implies not only speed of service, but also self-service, process visibility, and easy to use, streamlined, consistent, and reliable customer service. Lastly, cost refers to all objective and subjective costs that the customer incurs to acquire, use, and dispose of the good or service and includes dimensions such as discounts, rebates, and incentives. Customer value is enhanced as quality, speed, flexibility, and convenience increases while cost decreases. These five determinants of customer value creation may be referred to as core value determinants (CVDs) (Ramanathan, 2001). To ensure sustainable competitive advantage a firm must offer its customers a CVD profile that sets it apart from its competitors. Thus, in Stage 1 what is important is for the transferee firm to decide what technology or technologies it needs to create a unique CVD profile that will enhance its competitive edge vis-à-vis its competitors. The key activities that must be carried out at this preliminary stage of the technology transfer project are the following.

- An informal technology transfer steering committee (TTSC) is set up to study how competitors are using technology to enhance customer value and what technologies are available that could deliver even greater value.

- A list of technologies needed is developed and technology roadmaps are constructed to understand future trends of these identified technologies.

- Information for this is obtained through Internet searches, study of technical publications, exchange of communication with potential suppliers of technology, contacts with universities etc.

- A quick market assessment that examines market size, market potential, and likely market acceptance of the proposed initiatives is carried out, mainly through the use of marketing expertise and contacts with key users.

- A technical assessment is also carried out to estimate, approximately, the resources and capabilities needed to adopt the new technologies, time needed, costs involved, likely risks, and possible barriers (including policy, legal and regulatory aspects).

Gate 1: Confirming Identified Technologies

Gate 1 is a "critical but supportive" screen. The decision-makers, usually a top management team, develop a set of "**must meet**" criteria to review the proposal. The criteria could include:

- ✓ Strategic alignment
- ✓ Project feasibility in terms of technical and resource considerations
- ✓ Magnitude of opportunity
- ✓ Market attractiveness
- ✓ Sales force and customer reaction to the proposed technology
- ✓ Regulatory, legal, and policy factors

Financial returns are usually assessed at this gate using simple financial calculations such as payback period. The decision-makers will, at this gate, modify, confirm the composition of the TTSC which will then be in charge of the project.

Stage 2: Focused Technology Search

This is probably the most important stage where detailed investigation is carried out by the TTSC. It is here that a strong business case for the technology transfer is built. This includes specifying in detail the following:

- ✓ How the technology sought is expected to enhance customer value by influencing the CVDs
- ✓ What components of technology are needed (hardware, skills, information, and organizational arrangements)
- ✓ The extent to which the abilities to use the technology are available in-house and what gaps have to be bridged
- ✓ The resource commitments needed and the expected benefits
- ✓ Prioritised shortlisting of suppliers for the technology based on their business strategy, technological capabilities, experience in handling TT projects, past performance, and cross cultural expertise.
- ✓ Competitive analysis to assess the impact of the technology sought on competitiveness

Based on a consideration of these aspects, a business case is developed that includes clear technology specifications, discounted cash flow (DCF) analysis, project justification, and business plan. Development of this business case requires multidisciplinary interaction and cross-functional cooperation. If this stage is carried out poorly it could have adverse impacts at the remaining stages and cause serious difficulties.

Gate 2: Technology and Supplier Selection

This is the final gate prior to the formal negotiation and launch stage where the project can be killed before it enters a heavy spending phase. This gate gives the go-ahead for a "heavy spend." Gate 2 critically examines the analysis of Stage 2 and rechecks against the major criteria used in Gate 1. The following steps need to be followed very carefully at this gate.

- All suggestions with regard to technology choice, components of technology needed, capability gaps to be bridged, resource commitments needed, expected benefits, and supplier profile ratings are critically examined.

- The technology will be assessed very rigorously using techno-economic, socio, and politico-legal factors.

- The preferred supplier ranking will be reassessed rigorously based on strategic fit and process support capability and may be modified from the ranking proposed in Stage 2.

- The financial analysis (DCF) is rechecked very rigorously here.

- The TTSC may have to revise the analysis in the light of the critical evaluations (as indicated in the figure) and submit the new analysis for further evaluation.

If the decision is a Go-decision then the TTSC is converted to a full technology transfer project team that is empowered, multifunctional, and headed by a leader with authority.

Stage 3: Negotiation

This is a critical stage where the TTSC now negotiates with the shortlisted suppliers. A critical issue in TT negotiation is the valuation of the technology to be transferred. The extent to which both parties can influence price depends on their respective bargaining power. The transferor's power arises out of the resources possessed such as ownership of a desired technology, brand name, reputation, management expertise, capital, and international market access. Transferee power often tends to have its roots in local knowledge and networks, access to local markets, raw materials and low cost labor, and political connections. To ensure effective negotiation, frequent contact and communication between both parties is imperative. The following activities need to be carried out at this stage.

- Agreeing upon a basis for the valuation of the technology and reaching agreement on issues related to payments and intellectual property protection – both short-term and strategic benefits have to be examined.

- Delineation of each party's contribution and responsibilities towards the TT project

- Discussion of issues and methods related to the transfer of codified and uncodified aspects of technology including training

- Creation of effective channels of communication between both parties including visits to each others facilities
- Consultation with government authorities to ensure concurrence with government policies and identification of possible barriers, likely policy changes and government support available.

- Finalizing the most appropriate mechanism(s) for transferring the technology components sought.

- Preparation of a detailed transfer agreement with emphasis on ensuring intellectual property protection

- Reaching agreement upon payment amounts, procedures, and time frames

Gate 3: Finalizing and Approving Agreement

This gate is operationalised once the negotiations have reached a satisfactory level and the parties express the desire to finalize the agreement through the drawing up of a legal agreement. This gate will critically evaluate the following:

- The comprehensiveness of the detailed transfer agreement
- The adequacy of intellectual property protection arrangements
- The appropriateness of the proposed mechanism(s) for transferring the technology
- The suitability and affordability of the payment amounts, procedures, and time frames

Stage 4: Preparing a Technology Transfer Project Implementation Plan

At the beginning of this stage a transferor of technology would have been chosen and since the creation of a sound organisational infrastructure is critical to the implementation of TT, this stage focuses on making organisational arrangements to receive the technology. The main activities during this stage are the following:

- Identification of changes to be made to the organisational structure and work design based on an understanding of the transfer components
- Identification of changes to be made in the knowledge management system and policy regimes to accommodate the new technology
- Development of pragmatic training and education schedules for the workforce that matches with the components to be transferred
- Formulation of measures to build good relationships between the transfer personnel
- Formulation of a realistic TT project implementation plan that can form the basis of a working relationship between the transferor and transferee
- Milestones are specified to help strengthen project management and control.

Gate 4: Approving the Implementation Plan

At this gate, the following aspects will be carefully scrutinized:

- ✓ Whether agreement has been reached with the transferor with respect to the schedule
- ✓ Adequacy of the training arrangements
- ✓ Adequacy of the modification of the infrastructure
- ✓ Intellectual property protection measures
- ✓ Durations of critical activities
- ✓ Quality assurance procedures
- ✓ Payment schedules

If these are satisfactory then a go-ahead signal will be given. Otherwise revisions will be needed. At this gate an initial payment to the transferor, if specified in the agreement, will also be approved.

Stage 5: Implementing Technology Transfer

Technology transfer implementation requires good project management. Changes to product or process technology may sometimes be essential to the successful implementation of a TT project. Very often, firms in developing nations are confronted with finding suitable people at this stage and close cooperation with the transferor may be needed to locate required skills. Scheduling the timely arrival of allied materials, parts, and services is essential to ensure successful implementation of the project. Training programs will also have to be scheduled and conducted either in-house or at transferor approved locations. The major activities at this stage include the following:

- Identification of changes to be made to the product or process to suit local conditions and making the necessary adaptations.

- Recruitment and selection of personnel not already available within the organization and conducting training programs for existing staff.

- Development of improved remuneration plan to facilitate change management.

- Formulation of arrangements with ancillary suppliers of materials, parts and services based on a make vs. buy analysis

- Maintaining links with government authorities to keep track of policy changes

- Commissioning the transferred technology on or before schedule

Gate 5: Implementation Audit

At this gate the scheduled activities and the goals set for the TT project are evaluated. The focus should be on gaining an understanding of barriers to the successful implementation of TT. The audit may focus on the evaluation of project implementation with respect to critical factors such as:

- ✓ Commitment displayed
- ✓ Conflicts experienced
- ✓ Time frames
- ✓ Cost incurred
- ✓ Quality achieved
- ✓ Extent of learning and skill upgrading
- ✓ New knowledge generated
- ✓ Communication effectiveness

The compilation of a comprehensive audit report outlining the lessons learned and identifying critical success and failure factors is important at this gate so that future TT projects could benefit from these insights.

Stage 6: Technology Transfer Impact Assessment

Assessing the impact of a TT project is difficult because it is a complex process with multiple outcomes that could emerge throughout the life of a project. Also, the intangible benefits of a TT project are difficult to evaluate. However, a well structured impact assessment could be extremely beneficial and the impacts need to be assessed from customer, market, financial, technological, and organizational perspectives. The following activities are proposed for this last stage.

- Development of a "Balanced Scorecard (BSC)" approach to assess impacts.

- Identification of the variances (if applicable) between actual and expected outcomes and the formulation of organizational corrective measures.

- Examining the feasibility of improving the transferred technology.

- Identification of new or complementary technologies that could be transferred to consolidate the gains made.

Gate 6: Developing Guidelines for Post-Technology-Transfer Activities

At this gate important decisions have to be taken as to whether to continue to use the technology by improving it incrementally or go for another TT project. Successful TT projects can lead to strong and long partnerships between the transferor and the transferee and new projects could be initiated in a variety of ways. At this gate guidelines may be formulated, based on the experience gained at all the previous stages and gates for post-technology-transfer activities such as:

- ✓ A new technology transfer project
- ✓ Internal development
- ✓ A mix of both in partnership with the transferor.

These decisions can then be fed into the corporate planning process of the organization.

Summary Remarks on the TTLC Approach.

The TTLC approach is not purely conceptual. Its practical relevance, usefulness, and validity have been established through several case studies carried out by Jagoda (2007) in Australia and Sri Lanka. The main advantages of the TTLC approach are the following:

- The TTLC approach ensures that a TT project is considered holistically and incorporates much of the wisdom shared by various researchers and practitioners through their technology transfer models.
- The TTLC approach is structured to enable SMEs avoid many of the problems that they normally face when planning and implementing a TT project.

- It is a good way to incorporate cross-functional cooperation in planning and managing TT projects and also ensures that important activities are not forgotten or carried out carelessly.

- A single empowered team is responsible from start to finish. This avoids turf wars.

- All projects may not have to go through all the stages. Low risk projects may go quickly to the latter stages.

- The approach must not be seen as a bureaucratic system. It actually facilitates the development of a streamlined system with clear agreed upon, and visible, road map.

Clearly the success of the approach will depend upon the skills possessed by the managers involved in the TT project to carry out the activities effectively at the stages and gates. Thus, organizations that are serious in competing in today’s global business setting must develop such skills on a priority basis.

5. CONCLUDING REMARKS

This paper commenced with an overview of technology transfer and then presented some important models of technology transfer that have been developed over the decades to help firms plan and manage technology transfer projects. The strengths and weaknesses in these models were pointed out and an eclectic, process model titled, “The Life Cycle Approach for Planning and Implementing a Technology Transfer Project” is presented. It is envisaged that this model could help in addressing many of the common problems that are currently faced by transferees of technology, especially SMEs. This concluding section will briefly present an initiative that the UNESCAP Asian and Pacific Centre for Transfer of Technology (APCTT) is currently developing, based on the Life-Cycle Approach, to help technology transfer capacity building in the Asia-Pacific region.

The discussions presented thus far in this paper show that, unless a critical mass of skills to plan and implement a TT project are created in a country, SMEs of that country will continue to face difficulties in managing TT projects. Either the SMEs will have to develop these skills within the organisation or they must have access to these skills through technology intermediaries, SME support institutions, or consultants. The challenge for governments is to develop innovative ways by which the required critical mass of skills can be developed quickly within a range of SME-oriented institutions and within the SMEs themselves.

To help member countries in the Asia-Pacific region develop this critical mass of skills, APCTT is currently in the process of seeking funds to commence a technology transfer capacity building programme in SMEs.

To ensure that this capacity building effort reaches a larger group of SMEs through a “multiplier effect” the APCTT programme would adopt a “training of trainers” strategy. From participating member countries, carefully chosen trainers from SME support institutions, R&D organizations, universities, business and industry associations, and chambers of commerce would be trained extensively on technology transfer fundamentals and the use of the TTLC approach. These trainers would then be expected to return to their countries and train SMEs in their own countries through business and industry associations and relevant government organizations. APCTT would provide the trainers with all the relevant training materials that could be translated into local languages, if needed, and also used for online training and education.

Under this technology transfer capacity-building “training of trainers programme” participants will be imparted skills in the following areas:

- Preparation of a business case, based on market assessments, realistic forecast demands of the final product, and reasonably accurate operating costs, to show how the proposed TT project can enhance competitiveness, profitability, and growth.
- Construction of technology roadmaps in priority areas to define future trends to avoid the pitfalls of buying outdated, inappropriate technology and ensure non-obsolescence of technology;
- Preparation of a detailed technology transfer agreement
- Negotiation in today’s global business setting;
- Preparation of a detailed technology transfer implementation plan based on the decisions reached during negotiations; and
- Preparation of a scheme to assess the impact of a technology transfer project from market, financial, technological and organizational perspectives.

The training material for this programme will be developed by APCTT. The training will be organized by APCTT in cooperation with ESCAP, other relevant international partner agencies, government agencies, chambers of commerce and business and industry associations.

It is envisaged that this capacity building programme will help SMEs to better utilise existing APCTT web-based initiatives such as the Technology4sme (www.technology4sme.net), Business-Asia (www.business-asia.net), the Asia-Pacific Traditional Medicine and Herbal Technology Network - APTMNET (www.apctttm.net), the Biotechnology Information Network for Asia – BINASIA (www.binasia.net), and the Asia-Pacific Technology Information Tracking and Unified Data Extraction (APTITUDE) search engine. To supplement these web-based initiatives, APCTT also comes out with publications such as the Asia Pacific Tech Monitor and the Value Added Technology Information Services (VATIS) in the areas of Ozone Layer Protection, Waste Technology, Biotechnology, Food Processing and Non-Conventional Energy

There is considerable knowledge that exists today that can help to develop approaches to enable SMEs to effectively plan and implement TT projects. What is perhaps missing is a well-funded and potent mechanism to collect this knowledge, codify it, and disseminate it among the nations of the South which perhaps need it more than the technologically and economically advanced nations of the world. The proposed APCTT initiative could be a useful starting point.

REFERENCES

1. Amsden, A.H., 1989. Asia's Next Giant: South Korea and Late Industrialisation. Oxford University Press, New York.

2. Arrow, K., 1969. Classificatory note on the production and transmission of technological knowledge. American Economic Review, Papers and Proceedings, May, pp. 244-250.

3. Autio, E. and Laamanen, T., 1995. Measurement and evaluation of technology transfer: Review of technology transfer mechanisms and indicators. International Journal of Technology Management, 10(7/8), pp. 643-664.

4. Bar-Zakay, S.N., 1971. A technology transfer model. Technological Forecasting & Social Change, 2, pp. 321-337.

5. Behrman J.N. and Wallender, H.W., 1976. Transfers of Manufacturing Technology within Multinational Enterprises. Ballinger Publishing Company, Cambridge, MA.

6. Bozeman, B., 2000. Technology transfer and public policy: A review of research and theory. Research Policy, 29, pp. 627-655.

7. Chantramonklasri, N., 1990. The development of technological and managerial capability in the developing countries. In: M. Chatterji, ed. Technology Transfer in the Developing Countries, the Macmillan Press, London.

8. Chen, M., 1996. Managing International Technology Transfer. Thunderbird Series in International Management. International Thompson Press, London.

9. Cusumano, M.A. and Elenkov, D., 1994. Linking international technology transfer with strategy and management: A literature commentary. Research Policy, 23, pp. 195-215.

10. Dahlman, C.J. and Westphal. L.E., 1981. The managing of technological mastery in relation to transfer of technology. Annals of the American Academy of Political and Social Science, 458 (November), pp. 12-26.

11. Dosi, G., 1988. The nature of the innovation process. In G. Dosi, G., Ed. Technical Change and Economic Theory. Printer Publications, London.

12. Durrani, T. S., Forbes, S. M., Broadfoot, C. and Carrie, A. S. 1998. Managing the technology acquisition process. Technovation, 18 (8/9), pp. 523–528.

13. Gibson, D.V. and Rogers, E.M., 1994. R&D Collaboration on Trial: The Microelectronics and Computer Technology Consortium. Harvard Business School Press, Boston.

14. Godkin, L., 1988. Problems and practicalities of technology transfer. International Journal of Technology Management, 3(5), pp. 587-603.

15. Habibie, B.J., 1990. Sophisticated technologies: Taking root in developing countries. International Journal of Technology Management, 10(1), pp. 489-497.

16. Hameri, A.P., 1996. Technology-transfer between basic research and industry. Technovation, 16(2), pp. 51-57.

17. Hayami, Y., and Ruttan, V.W., 1985. Agricultural Development: An International Perspective. The Johns Hopkins University Press, Baltimore.

18. Jagoda, K. I., 2007. A Stage-gate Model for Planning and Implementing International Technology Transfer. Doctoral Thesis. University of Western Sydney, Australia.

19. Jagoda, K. and Ramanathan, K., 2005. Critical Success and Failure Factors in Planning and Implementing International Technology Transfer: A Case Study from Sri Lanka, Refereed Proceedings (in CD-ROM) of the Portland International Conference on Management of Engineering and Technology - PICMET 05, Portland, Oregon, U.S.A, July 31-August 4.

20. Keller, R.T. and Chinta, R.R., 1990. International technology transfer: Strategies for success. The Executive, 4(2), pp. 33-43.

21. Klein, J.J. and Lim, Y. K., 1997. Econometric study on the technology gap between Korea and Japan: The case of the general machinery and electrical and electronic industries. Technological Forecasting and Social Change, 55(3), pp. 265-279.

22. Lee, J., Bae, Z. T., Choi, D. Y., 1988. Technology development process: A model for a developing country with a global perspective. R&D Management, 18 (3), 2pp. 35-250.

23. Lundquist, G., 2003. A rich vision of technology transfer technology value management. Journal of Technology Transfer, 28(3-4), pp. 284.

24. Mansfield, E., 1975. East-West technological transfer issues and problems, international technology transfer: Forms, resource requirements, and policies. American Economic Review, 65(2), pp. 372-376.

25. Mansfield, E., Romeo, A., Schwartz, M., Teece, D. Wagner, S., and Brach, P., 1982. Technology Transfer, Productivity and Economic Policy. Norton & Company, New York.

26. Mayer, S. and Blaas, W., 2002. Technology transfer: an opportunity for small open economies. Journal of Technology Transfer, 27(3), pp. 275-289.

27. Mittleman, J.H. and Pasha, M.K., 1997. Out from Underdevelopment Revisited: Changing Global Structures and the Remarking of the Third World. St. Martin’s Press, New York.

28. Morrissey, M.T. and Almonacid, S., 2004. Rethinking technology transfer. Journal of Food Engineering, 67(1-2), pp. 135-145.

29. Osman-Gani, A.A.M. 1999. International technology transfer for competitive advantage: A conceptual analysis of the role of HRD. Competitiveness Review, 9, pp. 9.

30. Phillips, R.G., 2002. Technology business incubators: How effective as technology transfer mechanisms. Technology in Society, 24, pp. 299-316.

31. Radosevic, S. 1999. International Technology Transfer and Catch-up in Economic Development. Edward Elgar Publishing, Massachusetts.

32. Ramanathan, K. A Taxonomy of International Technology Transfer Modes,” Proceedings of the Third International Conference on Operations and Quantitative Management, Sydney, December 17-20, 2000, pp 203-209.

33. Ramanathan, K., 1989. Evaluating the national science and technology base: A case study on Sri Lanka. Science and Public Policy, 15, 304-320.

34. Ramanathan, K., 1991. Technology assessment at the firm level, MOTIC Series #6, Bangkok: School of Management, Asian Institute of Technology.

35. Ramanathan, K. 1994. The polytrophic components of manufacturing technology. Technological Forecasting & Social Change, 46, 221-258.

36. Ramanathan, K., 2000. A Taxonomy of International Technology Transfer Modes, Proceedings of the Third International Conference on Operations and Quantitative Management, Sydney, 17-20 December.

37. Ramanathan, K., 2001, E-strategies for technological capability development, Proceedings of the Portland International Conference on Management and Technology, July 29-August 2, Portland, US.

38. Ramanathan, K., 2005. Competing through total technology management. Refereed Proceedings (in CD-ROM) of the Portland International Conference on Management of Engineering and Technology - PICMET 05, Portland, Oregon, U.S.A, July 31-August 4.

39. Ramanathan, K., 2007. The role of technology transfer services in technology capacity building and enhancing the competitiveness of SMEs. Mongolia National Workshop on "Subnational Innovation systems and Technology Capacity-building Policies to Enhance Competitiveness of SMEs." Organized by UN- ESCAP and ITMRC (Mongolia). Ulaanbaatar, Mongolia, 21-22 March.

40. Raz, B., Steinberg, G. and Ruina, A., 1983. A quantitative model of technology transfer and technological catch-up: The case of developed countries. Technological Forecasting and Social Change, 24, pp. 31-44.

41. Reddy, N.M. and Zhao, L., 1990. International technology transfer: A review. Research Policy, 19(4), pp. 285-307.

42. Robinson, R.D., 1991. International Technology Communication in the Context of Corporate Strategic Decision-making. In: R.D. ROBINSON, Ed. The International Communication of Technology: A Book of Readings. Taylor & Francis, London.

43. Rogers, E., 2003. Diffusion of Innovations. 5th Ed. The Free Press, New York.

44. Rogers, E.M. and Shoemaker, F.F., 1971. Communication of Innovations: A Cross Cultural Approach. Free Press, New York.

45. Sadowski, B.M., 2001. Towards market repositioning in Central and Eastern Europe: International cooperative ventures in Hungary, Poland and the Czech Republic. *Research Policy*, 30, pp. 711-724.

46. Schlie, T.M., Radnor A. and Wad, A., 1987. Indicators of International Technology Transfer. Centre for the Interdisciplinary Study of Science and Technology, North Western University, Evanston.

47. Sharif, M.N. and Haq, A.K.M.A. 1980. A time-level model of technology transfer. IEEE Transactions of Engineering Management, EM-27(2), pp. 49-58.

48. Siegel, D.S., Waldman, D.A., Atwater L.E. and Link, A.N., 2004. Toward a model of the effective transfer of scientific knowledge from academics to practitioners: Quantitative evidence from the commercialisation of university technologies. Journal of Engineering and Technology Management, 21, pp. 115-142.

49. Souder, W.E. 1987 Managing New Product Innovation, D.C. Heath, New York.

50. Souder, W.E., Nashar, A.S. and Padmanathan, V., 1990. A guide to the best technology transfer practices. Journal of Technology Transfer, 15(1-2),

51. Spivery, W.A., Munson, J.M., Nelson M.A. and Dietrich, G.B., 1997. Coordinating the technology transfer and transition of information technology: A phenomenological perspective, IEEE Transactions on Engineering Management, 44(4), pp. 359-366.

52. Steenhuis, H.J., 2000. International technology transfer: Building theory from a multiple case-study in the aircraft industry. Doctoral Thesis. University Of Twente, the Netherlands.

53. Takii, S., 2004. Productivity differentials between local and foreign plants in Indonesian manufacturing. World Development, 32(11), pp. 1957-1969.

54. UNIDO, 1996, Manual on Technology Transfer Negotiations. UNIDO (ID/SER.O/18), Vienna.

55. Zhao, L.M. and Reisman, A., 1992. Toward meta research on technology transfer. IEEE Transactions on Engineering Management, 39(1), pp. 13-21.