3. LITERATURE STUDY: HOW TO TRANSFER TECHNOLOGY?

A literature study was done to determine existing information on how technology should be transferred from one country to another when at different levels of technology utilization and know-how. The technology transfer process has some precautionary measures that should be taken before their technology transfer model is considered. These include:

- Awareness of critical needed factors for technology transfer. Technology transfer can only be done successful if the LDC is well aware of the critical needed factors (Section 3.1).
- Learn from previously made mistakes. Malfunctions in the technology transfer process are discussed in Section 3.2.
- In LDCs the continuous search for an appropriate technology must be made to suit unique local conditions and interfacing with, often older, existing technologies. The parameters of an appropriate technology for LDCs are discussed in Section 3.3.

One can furthermore only evaluate different technologies when completely certain about one's needs and capabilities and therefore section 3.3.1 are devoted to need- and capability assessment. When aware of the necessary (needed) factors, the development needs and capabilities and mistakes made in the past, a method on how technology should be transferred is needed. This chapter ending with Section 3.4 provides a discussion on possible existing technology transfer methods (models) found in the literature.

3.1. Critical Factors Needed for Successful Technology Transfer

The stakeholders of technology transfer must at all times be aware of the critical factors. These factors (illustrated in Figure 3.1 [7]) should be in order before technology transfer will benefit the transferor as well as the receiver. Some factors can be related to the country and the situation within its industry whilst other factors are related to the acquisition process (Left and right in Figure 3.1 and separated by the back thick line).

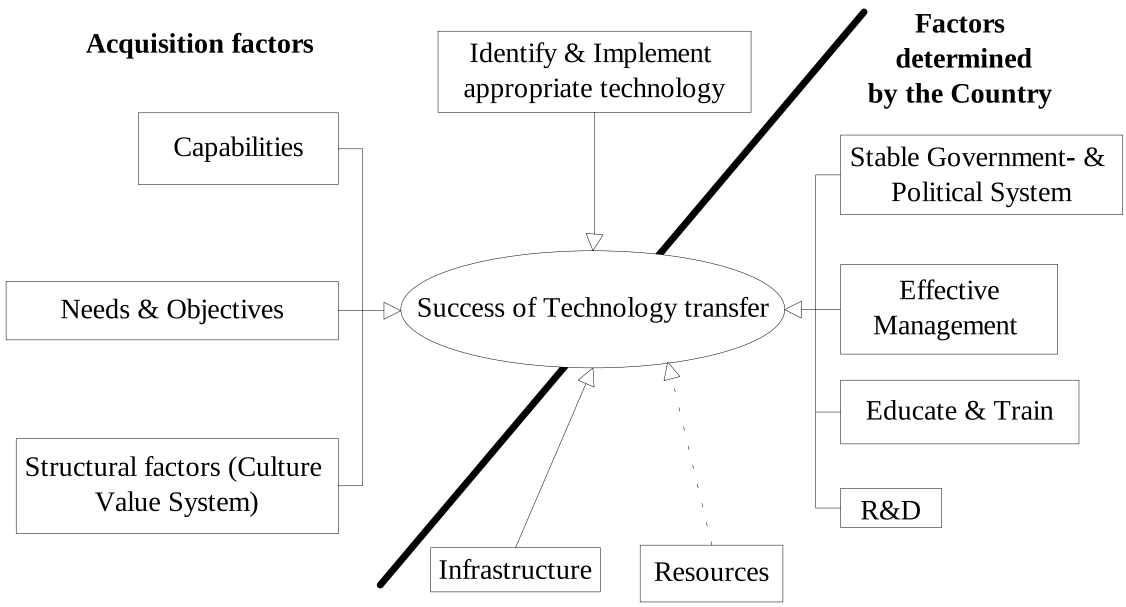

Figure 3.1 Critical factors for successful technology transfer

The link between resources and the success of the technology transfer process is indicated by the dotted line in Figure 3.1. The reason is that the availability of resources can be counterproductive if not managed effectively. Availability may help to trigger the development by using these initial advantages to explore, expand, and diversify the economy but the long-term development will never be assured. A more detailed discussion on this aspect is given below.

3.1.1. Stable Government and Political System

When governments restrict the exportation of certain technologies, as they normally do with defence technology, they protect their allies against potential enemies. Policies may also be enacted to protect a country's competitive edge. They then protect local manufacturers from foreign competitors and give them a competitive advantage.

The success or failure of transferred technology may depend to a large extend on the policies adopted by the receiver of technology. Investors are frequently very sensitive to political statements or actions due to the unusually high risks that may be involved in transferring technology to unstable economies.

Although it may often be necessary to enact laws to protect the receiver of the technology, attention should be paid to how such legislation may hinder technology progress. With fewer administrative controls and greater emphasis placed on innovativeness and entrepreneurship, local enterprises are more able to negotiate foreign collaboration agreements. The misdirected focus of some of the governments of the LDCs on technology as part of the foreign policy arena continues to limit and also hinder technology transfers. Analysis of the government's regulation, political history, and economic stability are usually done before MNCs engage in joint ventures with LDCs.

Emphasis should be on the long-term goal, potential and prospect of the LDC and also on what the MNCs (competitors) are doing in such environments. Beyond supplying technology to the LDCs, the MNCs have greater roles to play within the LDCs. If MNCs can effectively transfer appropriate technology to LDCs, the social and economic environment of the LDCs will be improved and a more conductive business environment suitable to the MNC's operation will be developed. Essentially, technology transfer to LDCs should be evaluated on its long-term merits by both the transferor and the transferee.

3.1.2. Management Process

Managers must be innovation orientated [7]. Managers should therefore be both sensitive to their environment and committed to the new technology. They must develop the ability to plan, diagnose and solve problems. They should also be familiar with organizational behaviour and the dynamics of the organization and able to manage change in an orderly fashion.

In order for technology to succeed and thrive in a LDC, an effective management of processes is required. Processes refer to organizational as well as production processes or more broadly speaking any process that has the capacity to transform input (raw material) into desired outputs. Thus, management of processes should also involve the management of human resources.

Effective management will lead to efficient utilization of the LDC's limited resources [7], making it possible for the LDC to plan the use of its resources. Appropriate educational programs need to be in place in order for a pool of effective managers to be developed. Management is a complex process, especially in the presence of new technologies. Technological and social changes should be anticipated scenarios. Managers should further understand the interactions and interdependence between their environments and the global environment, and how these influence the decision-making process. The management should thus be confidant about local conditions. Foreign managers rarely own the necessary skills to effectively utilize new technologies because of their lack in understanding local conditions and the current situation.

3.1.3. Education and Training

With effective training and educational systems, the LDCs are better able to improve and modify technology to suit their unique local needs [7]. In the absence of appropriate educational systems, LDCs will continue to be largely dependant on the transferor to supply the right labour force, to carry on technological innovations, and to engage in research and development [7]. The educational and training programs must address the needs and the problems of a LDC, and how they may be solved through technology. Without the proper educational system and training program, the receiver will not be able to fully utilize the transferred technology, let alone try to modify and improve on it.

Programs like on-the-job training, in-house training, seminars, and tuition reimbursements plans are often carried out to keep the workers abreast of technological changes. Creativity and the ability to modify technology exist only if those concerned have knowledge of the technology [7].

Cultural differences are seldom integrated in training programs developed for people in the LDCs. Cultural differences reflect the different environments of the receivers and the transferors of technology. A training program that works effectively in a certain country might be inadequate to a LDC [7]. Perhaps something may be learned from how the technology operates in other environments, but each country must be viewed differently.

The transfer of technology can also have a positive effect on this critically needed factor. With technology from MNCs, education that will strengthen the LDCs' capabilities could follow. A brief discussion on this topic will now be done.

Training of Local Employees in MNC Affiliates

The transfer of technology from MNC parents to affiliates is not only embodied in machinery, equipment, patent rights, and expatriate managers and technicians, but also realized through the training of the affiliates' local employees [14]. These include people from simple manufacturing operators, supervisors, technical advanced professionals and top-level managers. Types of training range from on-the-job training, seminars, formal schooling and overseas education (perhaps at the patent company depending on the skills needed) [14].

The various skills gained while working for an affiliate may spill over as the employees move to other firms, or set up their own businesses. The public educational system in LDCs is relatively weaker and spillovers from training are much more important for the LDC [14]. The mobility of employees in the MNCs contributes to spillovers, both within the industry and elsewhere.

Managers move from MNCs to other firms and contribute to the diffusion of know-how [14]. This mobility of managers in MNCs seem to be lower than for managers in local firms, because MNCs pay more for their labour than local firms do, even when skill levels are taken into account. Another reason is because of the fear that MNCs have of a "brain-drain" to local firms.

MNC's training expenditures are significantly (several times) higher than those of local firms [14]. Chen studied technology transfer in Hong Kong (1983) and concludes "the major contribution of foreign firms in Hong Kong manufacturing is not so much the production of new techniques and products, but the training of workers at various levels" [14].

By recognizing the impact of the LDC's structure on technology, appropriate education systems and training would enable the members of the LDC to devise means of working with and taking advantage of their limitations [7]. In addition, innovative measures may be developed to satisfy the LDC's needs in the light of these limitations.

3.1.4. R&D Inter-firm Agreements in Developing Countries

MNCs undertake R&D in their host countries, although it is strongly concentrated to the home country's R&D. The affiliates' research effort should be compared with R&D [14] efforts of local firms, rather than with the parents' total R&D. The affiliate firm has access to the know-how of the parent and related affiliates, and sometimes also to the parent's R&D facilities. The affiliates' R&D may therefore be more efficient than that of local firms.

Foreign investments and inter-firm contractual agreements are the main channels for the diffusion of technologies towards LDCs [39]. Knowledge is an important determinant for the decision of starting production abroad. R&D are often carried out by networks of firms located in different countries, and even in LDCs. R&D cooperation seems to be the only way for most firms to participate in the extremely expensive R&D phase of the product-life-cycle. This occurs, even under rather unexpected conditions, i.e. when firms compete in the product market and when endowments of knowledge across partners are asymmetric [39]. Partners in the joint venture are and remain independent units with partly common but partly conflicting objectives.

Dispersion R&D seems to be increasingly related to the need to exploit specific and localized technological knowledge or networks of innovation. This occurs in two ways namely: Vertical and Horizontal Investments:

- ***Horizontal Investments:***
  Horizontal investments imply the reproduction abroad of production processes already carried out at home [39]. They may concern the whole production process or only a few stages. Overseas R&D by subsidiaries of MNCs is mostly carried out to adapt to local market, i.e. in relation to horizontal investments.

- ***Vertical Investments***
  Vertical Investments refers to the setting up abroad of production processes or stages of production, which are not carried out at home yet [39]. Vertical Investments are fostered by trade liberalization, increasing labour cost in the industrialized world and raising global competition.

3.1.5. Resource Availability

Most of the LDCs relay largely on foreign aid to sustain their growing population. Some OPEC (Organization of Petroleum Exporting Countries) nations expected oil prices to continue to skyrocket to their own advantage, and they ruled out the possibility that alternatives to oil can be devised or the fact that consumer patterns may change as a response to high prices. Basically these resource-laden nations developed a one-base economy [7]. Thus, the availability of resources can be counterproductive if not manage effectively.

The long-term economic prosperity of a nation may not be totally dependant on the availability of its natural resources. Availability may help to trigger the development by using these initial advantages to explore, expand, and diversify the economy. Complete dependence on these mineral resources, which are depletable and normally not replenishable, will eventually lead to economic problems. Nations should acknowledge their limitations and devise innovative ways to make good out of these weaknesses. The availability of natural resources is not a necessity for the development of a country as will be shown below [7].

1. Switzerland is a land locked nation with a high cost of labour, strict environmental laws and few natural resources (least of all cacao). Yet, it is the world leader in chocolate, not to mention pharmaceuticals, banking and specialized machinery.

2. Japan, which is severely limited in terms of natural resources and the availability of usable land, has emerged as a leader in most industrial and consumer goods. Much of the success achieved by Japan can be attributed to the country's economic disadvantages. For example, strategies such as just-in-time manufacturing and shorter production lines exploit the fact that there are limited spaces, which can be used for inventory or manufacturing.

3. Taiwan is one of the most densely populated regions of the world with 546 persons/km^2. Only one quarter of the land is arable, two thirds is forest (highly limited because of poor accessibility), and it is poor in minerals and fossil fuels In spite of all these difficulties, Taiwan emerged as one of the newly industrialized countries (NICs).

Once LDCs understand that foreign aid implies economic dependence and that it represents only a temporary solution to their greater problems, more proactive remedies are likely to be developed [7]. LDCs should look at the history of other nations with similar characteristics and structures, which have benefited greatly from technology transfer, and learn from them. Natural resources are absolutely not a necessity for sustainable national development.

3.1.6. Infrastructure

Structural changes take place as a result of technology transfers [7]. These changes influence both the social and economic conditions of the LDC. Although we may be able to predict the direction of the changes, we may never know the magnitude. The concept of infrastructure consists of four principal dimensions [40] as presented in Figure 3.2.

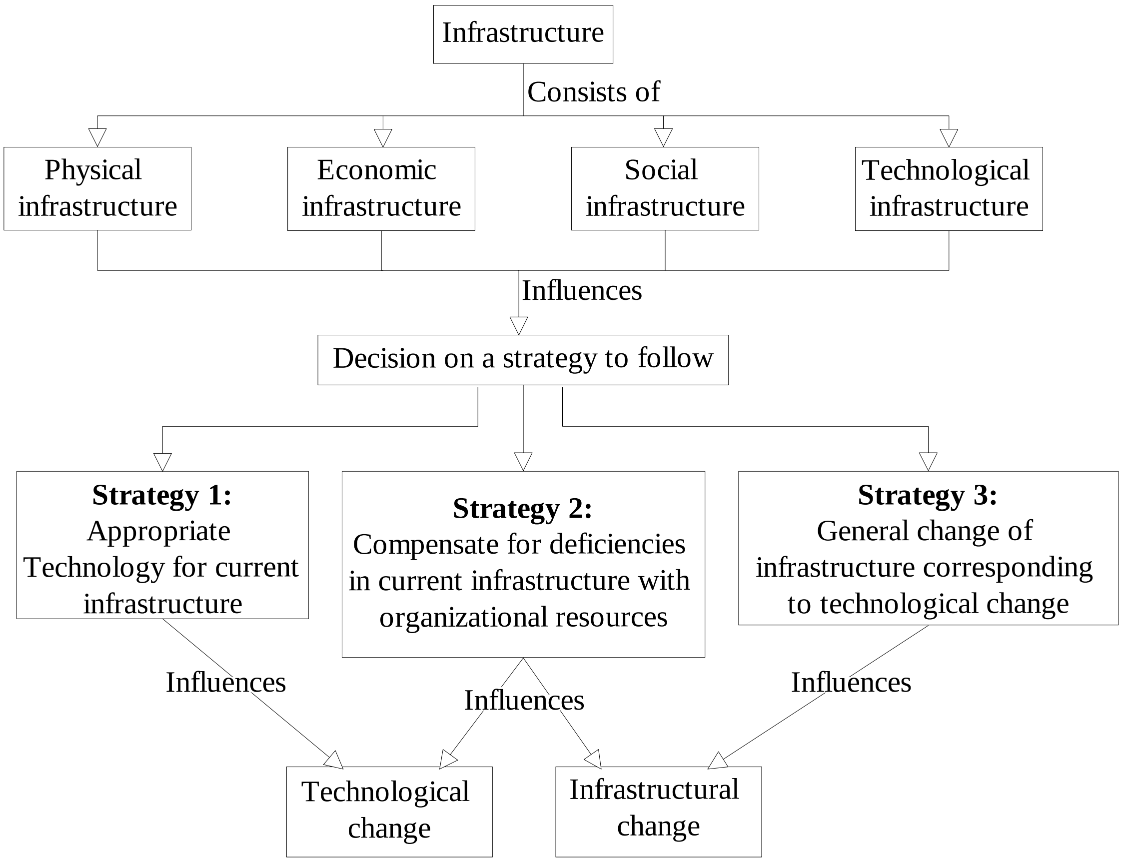

Figure 3.2. Division of Infrastructure in Technology Transfer [40]

The four principal dimensions are:

- ***Physical Infrastructure***
  The physical infrastructure includes systems of transport, energy, telecommunication, and to some extend different types of public works. This part of the infrastructure makes possible the movement of goods, labour, and other inputs to the production.

- ***Economic Infrastructure***
  Economic infrastructure consists of the channels through which the actors of technology obtain access to financial resources to realize their transactions with other production units and actors (the capital market, credit institutions, regulations of investments, and subsidies).

- ***Social Infrastructure***
  Social infrastructure consists of systems for health and education particularly seen as a matter for the qualification of the labour force. It also covers the structure and the functioning of the labour market.

- ***Technological Infrastructure***
  Technological infrastructure covers various types of institutions dealing with the generation and diffusion of technology and the education of scientific personnel.

Until today mainly the physical dimension of infrastructure has been developed internationally, but efforts are being made to extend the international scope of infrastructure to the social, economic, and technology dimensions of infrastructure as well [40]. This must be seen in relation to the requirements of the new technology.

The optimal function of a given technology requires infrastructural equipment of a certain quality and quantity. The level of the infrastructural dimensions therefore decisively influences the behaviour of the carriers of technology. Confronted with infrastructural constraints the carriers choose between three different strategies [40] as presented in Figure 3.2. These are:

- ***Appropriate Technology for current infrastructure:*** Adjust the project fully to the given infrastructure conditions, by limiting its scope, reducing its quality and finding new ways to use the given resources. No important technological changes can take place without corresponding infrastructural development.

- ***Compensate for deficiencies in current infrastructure with organizational resources:*** Dedicate some of the organization's resources to compensate for the deficiencies of the given infrastructure, typically through in-house training and education, private road telecommunication construction, and other private systems of transportation etc. This strategy implies a spread of resources away from the main activity and calls forward the necessity of a broader technological capability. This strategy thus, diminishes the possibility of specialization.

- ***General change of infrastructure corresponding to technological change:*** A course of general change of the infrastructure corresponding to the technological change can be considered. However, this possibility is seldom within the reach of individual actors at micro-level. Mostly such changes can be carried out only by the state or large groups of micro-carriers.

The first strategy has been called *appropriate technology*, but it is doomed to be a blind alley as stagnation will be an inherent characteristic [40]. The second strategy will be relevant in relation to projects of technology transfer from developed countries to LDCs. It implies a move of technology from well developed to less-developed infrastructural surroundings. The third is the only one with more far-reaching and dynamic implications. A more or less simultaneous change of technology and infrastructure is optimal to technology and socio-economic change, and should always be considered as crucial in any policy of technological change [40].

3.1.7. Cultural Value System

Technology has an impact on the cultural value system of the receiving nation. The cultural value system needs to be integrated into the planning process for the technology transfer. Culture is a sensitive aspect to most LDCs. Analysis of the culture will identify things that are of value to the people of a particular LDC together with those factors, which motivate them to work [7]**.** It is in an attempt to protect their culture that the members of the LDC often reject technology. Knowledge of the integration of the LDC's cultural value system into technology transfer decision-making will enhance the successful transfer of appropriate technology.

Need Capability assessment together with the identification and implementation of the technology will be discussed in the Technology transfer model formulation section.

3.2. Malfunctions in the Technology Transfer Process

The failures of technology transfer to a LDC can be mapped in three different dimensions [7] namely structural, technological end behavioural functions, which can also be used to characterize a particular country.

3.2.1. Structural Failures

Structure refers to the different local governments, ethnic groups, government agencies, or the private sector. These groups may exercise different levels of control and influence on the decision to transfer of technology. Structural failures may be due to failures of *logic, adaptability and regulations* [7].

1. The ***logic*** levels often provide the knowledgebase and the methods of reasoning to solve the problem. Technology transfer involves the transfer of logic levels (also see "Knowledge" component of the Technology Triangle of Appendix A).

2. ***Adaptability*** requires that adjustments be made to accommodate a changing environment by either seeking to control the environment, or by adjusting internally in accordance with external changes [7]. The long-term economic growth of LDCs will depend on their ability to maintain, adapt, and improve the transferred technology in their own unique ways. What is often at fault is not the people's culture but the inability to understand how to adopt technology to these different cultures [7].

   Once installed, it is often necessary to adapt imported equipment or procedures to local conditions. These might include physical, climatic, and temperature conditions [8]. Adaptation may also be necessary because the inputs, which are utilized and locally sourced, are not the same as those for which the equipment was designed.

   The problem of adaptation does not apply only to the operation of physical equipment. Even managerial procedures may require some adjustment. Educational policies need to be tailored to meet requirements of technology acquisition, adaptation, and development. With the absence of sufficient maintenance staff, an adjustment to the equipment that is purchased might be required. The problem of adaptation is often neither simple nor of trivial importance. In some cases it may require relatively sophisticated inputs of skill of information, drawing on the experience of other local firms. It may also not be possible to undertake adaptation without assistance either from government, from the tertiary educational sector or form specialized consultants. In Africa [8], various empirical studies have shown that the primary source of technological change within firms arose not from formal R&D activities, but from efforts to adapt equipment and procedures to the local conditions.

Structural malfunctions occur when the organization is unable to adopt. The introduction of the technology has to be gradual [7] in order for it to be successfully incorporate and absorbed into the environment of the LDC.

3. When there is no agreement between the mindscapes of the designers and those of the users, problems may arise. It is then necessary to solve this through ***regulations*** on consensus seeking methods. One, who possesses technology, may not necessarily posses the authority to implement the logic levels. Consequently, technology transfer fails when logic and authority levels are not unified [7].

3.2.2. Technological Failures

A country's competitiveness and productivity is to a large extent dependant on technology [7]. Technology involves hardware and software. Hardware is the design of equipment, machinery and instruments, while software is data, information and management systems.

Technology malfunction occurs when an inappropriate technology is transferred which is unable to satisfy the needs and aspirations of the LDC [7]. The solution that the transferor and the receiver develop is linked to their backgrounds, which influences the ways that information is analysed. Misconceptions can be avoided if they recognize and respect each other's perceptions of the problem. Differences such as cultural value systems, environments, work ethics, motivations, and capabilities have to be considered in order to successfully transfer technology to LDCs.

Other circumstances that are significantly different in LDCs than in the industrialized countries are [13]: religious situation, demographic features, relatively low GNP and salaries, high unemployment rates, financial depths to international institutions, ineffective land policies and lack of valid (up-to-date) information.

3.2.3. Behavioural Failures

The purpose of an organization may be religious, economic, charitable or social and the existence of such goal structure gives rise to what are typically called institutions [7]. The formation of an institution's goal structure requires human input. As the LDCs embark on a mission to transfer and develop technology, the humanistic and behavioural aspects of such decisions need to be evaluated.

Decisions have to be made on the introduction, maintenance and enhancement of technology. These decisions may be objective or subjective. Assumptions often made in solving purely technological problems, are not applicable when socio-technological issues are involved. Decisions are subjective in a sense that they are influenced by a combination of factors including models, worldviews, environment, cognitive dissonance and human judgment [7].

The increasing role of ethnical and cultural issues in the successful transfer of technology suggests that simple models cannot be relied on in order to transfer technology successfully [7]. An appropriate model should be able to integrate most of the socio-technological variables with an understanding that satisfactory rather than an optimal solution will be achieved.

Policy planners should develop adequate means of dealing with controllable factors and also be able to anticipate and plan for some of the uncontrollable factors [7].

Transferred technology may also fail if it is insensitive to the values and believes system of the LDC. Sensitivity towards culture will ensure acceptance of the technology and enhance the implementation thereof [7]. This issue thus brings the topic of a cultural value system into the discussion.

3.2.4. Failure to Enrich the Culture Value System

Acceptance of technology for socio-economic development may depend on how well technology is integrated into the culture value system of the LDC [7]. In transferring technology to different environments, a bond between technology and culture should always be identified.

It is further to the advantage of the transferor to understand how technology may be used to enrich some cultural goals. Society develops through “enriched” strategies. Rather than seeking to substitute or displace an existing social system with another by overemphasizing the role of technology in a different environment, the transferor should seek to offer the LDC technological enrichment [7]. One way culture can be enriched is through the gradual transfer and implementation of appropriate technology which can satisfy the needs and aspirations of the LDC, make use of their limited resources, and provide increased opportunities for the people.

3.3. Need- and Capability Assessment

In a literature study the author found four approaches to the transfer of technology. These will be discussed later. They all had one objective in common and that is to obtain the country’s needs and capabilities. This issue of defining a country's needs and capabilities will thus firstly be discussed.

Effective technology transfer and technology development requires a thorough analysis of the LDC’s needs and capabilities. This enables the LDC to clearly identify its strengths and weaknesses and match them to the different technologies.

Environmental analysis should be conducted to anticipate and perhaps develop strategies to manage impacts of uncontrollable factors. Controllable factors on the other hand should be planned for and managed. Resources determine the ability of the LDCs to afford or develop technology, supply the skilled labour force, develop the required raw materials, develop management and technical skills, afford adequate maintenance of machinery, or to carry out effective research and development programs [7]. Natural resources and labour force can be a competitive advantage to the LDC but increasing emphasis on high technology has significantly diminished the labour advantage.

Value analysis deals the assessment of socio-economic growth, efficiency, technology utilization, and cultural values. Appropriate technology must satisfy these goals [7] at reasonable social and economic costs, be sensitive to short- and long-term goals, enable LDCs to solve domestic problems such as unequal distribution of income, restricted social mobility, and poor education and training, which limit socio-economic growth. The needs of a LDC refer to the aims to satisfy the purpose or mission such as socio-economic development, competitiveness, technological progression, and the ability to satisfy local demands.

3.3.1. Finding the Appropriate Technology

3.3.1.1. Need-Capability Assessment Matrix

The Need-Capability Assessment Matrix is a 3 × 3 matrix, which positions the LDC in terms of its needs and capabilities for a specific technology. A specific technology that is being evaluated will fall in one of the cells in the Need-Capability Assessment Matrix. The Need-Capability Assessment Matrix was also suggested as a method for obtaining one's needs and objectives in the model for Telecommunication Technology Transfer/Diffusion into Rural Areas of South Africa (section 4.3, Chapter 4). The columns represent the LDC's needs while the rows represent capabilities that are necessary to support this technology as shown in Figure 3.3 [7].

Capabilities \ **Needs**	Low (1)	Medium (2)	High (3)
Low (1)	1	2	3
Medium (2)	2	4	6
High (3)	3	6	9

Scale	**Statement of Importance**
1	Undesirable
2	Least desirable
3	Desirable with risk
4	Desirable with little risk
6	Very desirable
9	Highly desirable

Figure 3.3. Need-Capability Assessment Matrix

The value within each cell of the matrix is determined through multiplication of the values associated with the capability of that specific row and the need of that column. The cells with a value of 1 are undesirable and no further time should be spent analysing any technology that may fall there. The cells with a value of 2 are least desirable but might represent opportunities that need to be developed and become of strategic importance if more attractive cells cannot be presently obtained. Further evaluation might be required in order to determine whether capabilities can effectively be developed or whether demand can be generated. The cells scoring a value of 3 or 4 in the matrix, offer good support for future considerations of the technology. Questions that have been addressed here are [7]: Can sufficient capabilities be developed to satisfy the high need? Can new demands be created to support technological services? The cells containing a value of 6 must definitely be considered as a potential technology to transfer. The established needs and capabilities indicate that technologies in these cells may play a vital role in achieving the missions of the LDC. Finally, the most desirable cell with a value of 9 gives no doubt that a technology that assumes this position must be transferred.

The Need-Capability Assessment Matrix serves as a screening process assisting in narrowing down the list of technologies to be considered for transfer [7]. Technologies with a value of 1 or 2 should be dropped, while those with scores of 3 should be evaluated further. The result of the evaluation should determine whether or not they should be included in the list of potential technologies to transfer. Those with scores 4, 6 and 9 are considered desirable and are passed on to the next stage of decision-making.

3.3.1.2. Applying Need-Capability Assessment Matrix

Firstly a LDC should specify their mission. A group of stakeholders should then be commissioned to undertake the task of identifying needs of the LDC and technologies, which might fulfil those needs considering their capabilities [7]. The identification process can be achieved through a brainstorming technique. Each of the stakeholders independently generates a list of needs and capabilities, which are then combined and redundancies eliminated. The combined list is then analysed and values (between 0 and 10) denote the importance of the technology in relation with the needs and the capability of the LDC to support the technology.

Let W_{ijk} represent a weight assigned by stakeholder i, when comparing need, j, to technology, k, and i = 1, 2, 3, ...N; j = 1, 2, 3, ...M; and $0 \leq W_{ijk} \leq 10$. Thus, for any given technology k, the combined score assigned by N stakeholders based on M needs of the LDC can be obtained as:

$$\sum_{i=1}^{N}\sum_{j=1}^{M} W_{ijk} \tag{3.1}$$

An example of a weight assignment for need assessment is shown in Figure 3.4 [7].

	Socio-economic growth	Revenue generation	Employment opportunities	Enhanced competitiveness	Total
Stakeholder 1	5	4	5	3	**17**
Stakeholder 2	7	4	5	6	**22**
Stakeholder 3	4	3	8	7	**22**
Total	**16**	**11**	**18**	**16**	61

Figure 3.4. Weight assignment in the need assessment process

Similarly the combined score for any given technology given the capabilities of the LDC can be obtained. A Weighted factor for technology k can be calculated as:

$$\frac{\sum_{i=1}^{N}\sum_{j=1}^{M} W_{ijk}}{10 \times N \times M} \tag{3.2}$$

Thus, the weighted factor for technology k of Figure 3.4 is 61/(10×3×4) = 0.51. However, to implement this score into the Need-Capability Assessment Matrix, we must further multiply this weighted factor by 3 which is the maximum scale used in the axes of that matrix. Thus, we obtain a need desirability factor for technology k on the basis of needs through:

$$\left[\frac{0.3 \times \sum_{i=1}^{N}\sum_{j=1}^{M} W_{ijk}}{N \times M}\right]^{+} \tag{3.3}$$

where $[]^+$ refers to the closest integer.

Thus, the need desirability factor for technology k of Figure 3.4 is $[(0.3\times61)/(3\times4)]^+ = [1.53]^+ = 2$ (thus column 2). Similarly, the capability desirability factor for technology k on the basis of capabilities can be assessed. An example of a weight assignment for capability assessment is shown in Figure 3.5.

	Effective waste management	Labour requirement	Supporting services	Financial requirements	Organizational management	Resource development	Supporting industries	Total
Stakeholder 1	5	4	5	3	4	5	3	**29**
Stakeholder 2	2	3	5	2	3	5	2	**22**
Stakeholder 3	4	5	6	7	5	6	7	**40**
Total	**11**	**12**	**16**	**12**	**12**	**16**	**12**	91

Figure 3.5. Weight assignment in the capability assessment process

The capability desirability factor for technology k of Figure 3.5 [7] is therefore $[(0.3\times91)/(3\times7)]^{+} = [1.3]^{+} = 1$ (thus row 1). The position on the Need-Capability Assessment Matrix is then fixed for a specific technology and the value within the cell calculated by multiplying the need desirability factor with the capability desirability factor, which is 1 × 2 = 2 for the technology in Figure 3.4 and 3.5 (Least desirable and should be dropped).

Need-capability assessment is not the only factor that determines appropriate technology. Figure 3.6 [7] identifies the major determinants of appropriate technology transfer.

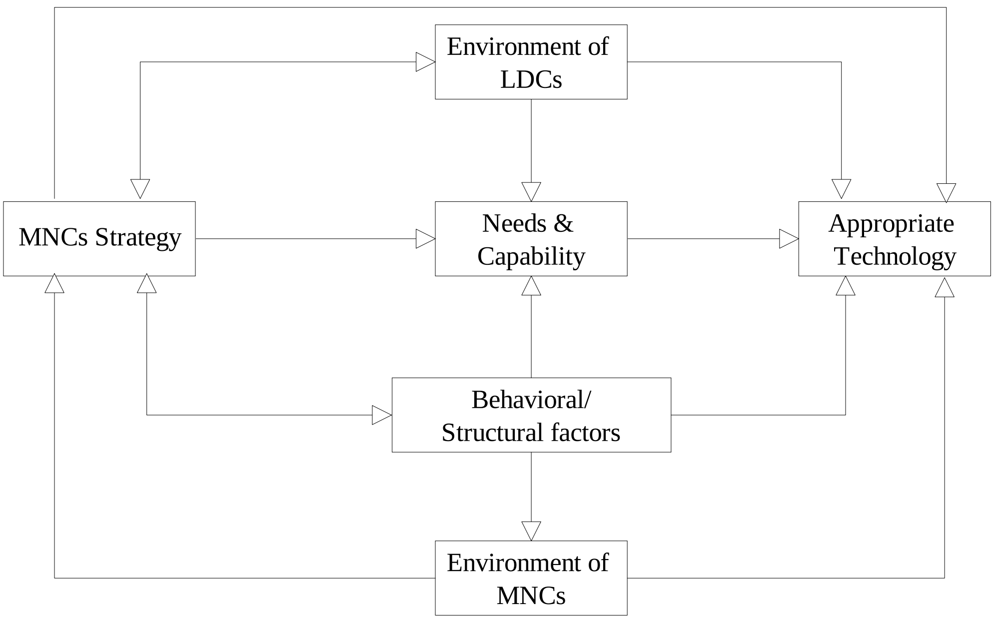

Figure 3.6. Determinants of appropriate technology transfer

This relationship makes it clear that the nature of needs- and capability assessment is one of interdependency. The other determinants' impacts need to be understood by the stakeholders. Each determinant will now be discussed briefly.

The Environment of the LDC

The environment of a LDC influences its needs and capabilities. Some needs are related to the social environment where social conditions imply obsolete land ownership systems, unequal income distribution, inequalities of ethnic integration, segmentation of production and marketing systems, inequalities in varies socio-economic groups in education and training and restricted social mobility.

The political structure of a country also influences demand and development of resources. Entrepreneurship has to be encouraged in the LDCs and their governments should expand their role by funding R&D programs. LDCs account for less that 3% of the total world expenditure on R&D while U.S.A. accounts for 33%, Western Europe and Japan for 33% and the Soviet Union and Eastern Europe for about 31% [7]. These data may explain comparative technological disadvantage on the part of the developing countries. To develop efficient capabilities requires effective R&D.

The Environment of The Transferor or MNC

The transfer of "sensitive" technologies is limited and existing patent law and government policies all influence the ability of the LDC to legally acquire technology. The constraints imposed in terms of leverage allowed to the LDCs may hinder the utility of such technologies for achieving national goals. In conducting the need-capability assessment, these limitations and their ramifications are evaluated. When the LDC is unable to unbind from these restriction, the capability to effectively transfer the technology is severely limited and other potential transferors with more conductive environments should be considered. The environment of the transferor will also dictate the quality and the demands of the technology.

The world today is concerned with issues such as environmental and atmospheric pollution, labour displacement, the erosion of cultural value systems, and social inequalities that result from technological developments. Quality of technology should be evaluated not solely on the basis of finished products and services but also on the environmental impact [7] and its ability to satisfy the mission of the LDCs.

Behavioural and Structural Factors

Technology must interface with the human labour force. This means that various components of human factors are involved, which can be divided into three groups [7]:

Safety Factors: Unfortunately when technologies are transferred to LDCs, less stringent controls are applied, following the argument that the costs of implementing these safety programs are too high.

Social Environment Sensitivity: Laws are used to guide industries in the disposal of pollutants, especially the chemical, oil and nuclear industries. It is not incidental that some of the major corporations in these industries operate abroad, especially in the LDCs where less stringent environmental laws exist to protect the quality of the environment [7]. This short-term approach to profit is gradually threatening the security of the whole world as the concerns over the effect of global worming illustrates.

Decision Process: Technology relates to processes of production, while the human's ability to make decisions helps in the effective running of the technological processes. Effective decision-making requires manpower development and training. The reasoning and thinking processes or the worldviews of these decision-makers are influenced by their cultural and ethnical value system.

The environment of the LDC can influence the strategy adopted by the transferor, while at the same time the transferor's strategy can influence the LDC's environment. However, the effective development of a strategy must be based on a need-capability assessment and social impact analysis. Performance measures are then used as control mechanisms in evaluating the ability of the technology to continuously satisfy society's needs.

A decision can be made whether to modify the technology or retain it as is. This decision, however, is based on feedback received from the set performance measure. Policy makers in LDCs should paradoxically be both forward looking and introspective [7]. They must realize that successful transfer of technology is influenced by factors that are both internal and external to their environments.

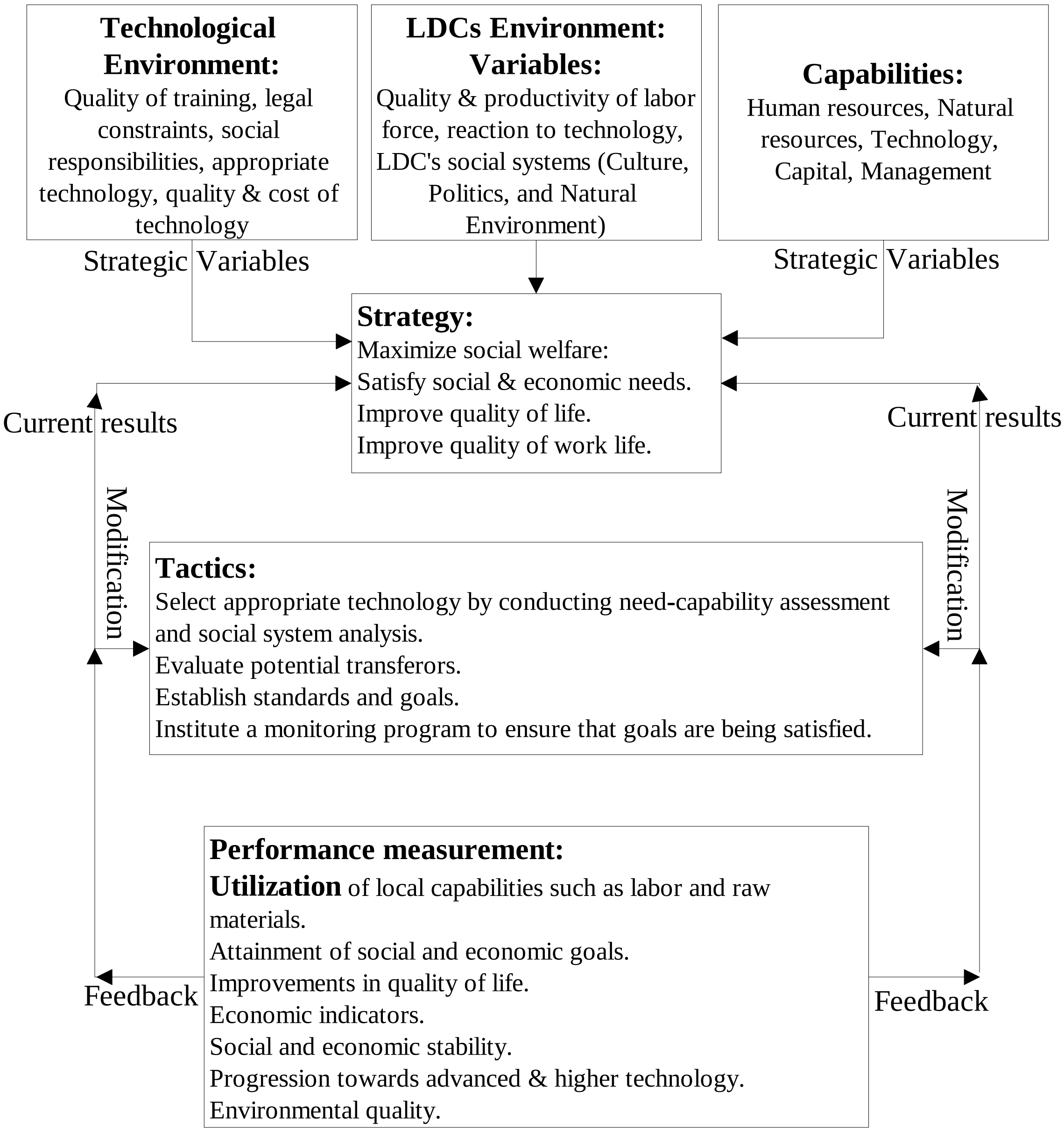

Figure 3.7. Continuous Strategic Planning/Feedback Loop [7]

3.4. Generating a Technology Transfer Model

The technology transfer problem viewed in an economic context neglect the interconnectedness between technology, the economy, and the other important subsystems of LDCs. Subsystems account for aspects such as socio-economic, environmental, cultural values, and political systems which must be integrated into the planning framework for technology transfer. Questions that need to be answered in transferring technology include the following [7]:

- What technology to transfer?
- How many national resources to devote to each technology type?
- From where to transfer the particular technology?

- What is the future of the technology once it is successfully transferred?
- What are the transferor's and receiver's strengths and weaknesses, and how can these be effectively used to transfer technology to the receiver?
- Why do we need technology?

The five different but complementary technology transfer approaches found in the literature are briefly discussed below. They are:

1. A Prescriptive Framework for Technology Transfers.
2. Strategic Planning in Technology Transfer.
3. Strategic Planning Dialectical Approach.
4. A Systems Approach to the Transfer of Mutually Dependant Technologies.
5. The Technology Acquisition Hierarchy (TAH)

3.4.1. A Prescriptive Framework for Technology Transfers

Figure 3.8 presents Madu's [7] step-by-step approach towards technology transfer.

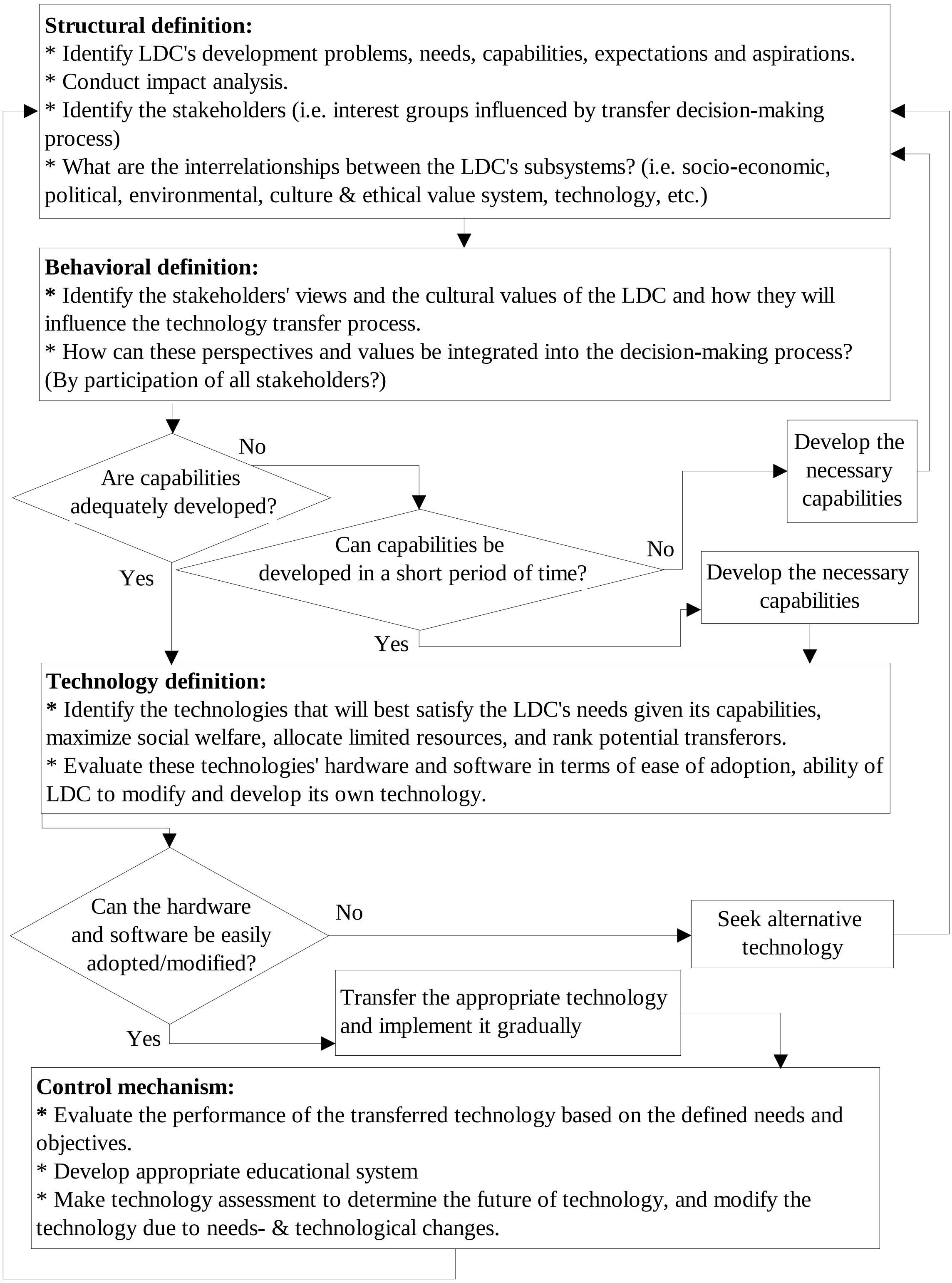

Figure 3.8. A Prescriptive Framework for Technology Transfers

This framework breaks down the technology transfer problem by specifically considering the three major dimensions of failure in the technology transfer process (see Section 3.2).

By doing so the policymaker is made aware of the role of each of the system dimensions in achieving the LDC's technological goals.

An appropriate technology refers to a technology that will provide to the needs of the LDC at a minimum social- as well as economical costs and maximize utilization of capabilities to become independent from the transferor [7]. The needs and capabilities are determined in the Structural phase through a Needs-Capability Matrix.

3.4.2. Strategic Planning in Technology Transfer

The definition of planning consists of three phases. They are presented in Figure 3.9.

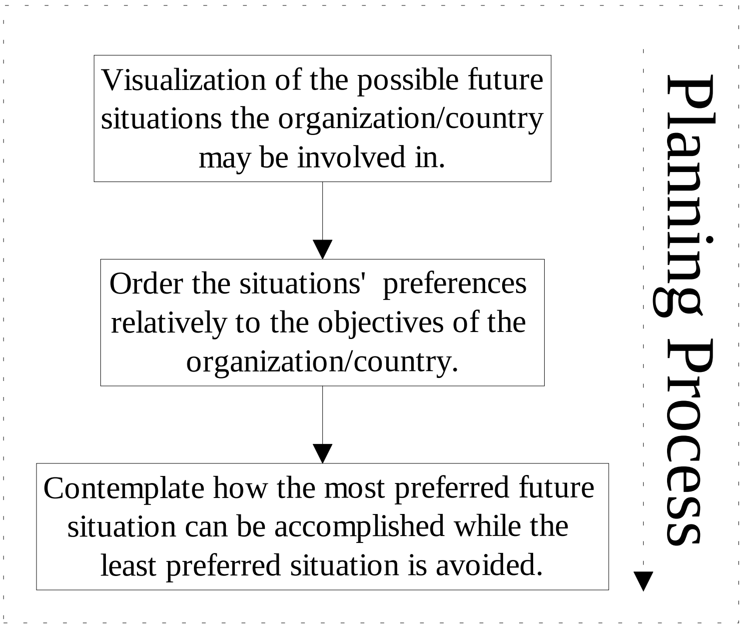

Figure 3.9. Diagrammatic Definition of Planning

An implication of the partnership between the MNCs and LDCs is that two parties often have different goals and objectives. Specifically, the MNCs are profit-orientated while public institutions often adopt goals more socially responsive. Recent controversies have centred on the marketing of expired drugs, unproved products, which are still in the test phase, baby formulas, and increasing attempts to dump nuclear wastes in these impoverished nations. The tolerance of both parties concerning conflicting objectives and the need to achieve compromise may reinforce and enhance technological decisions.

MNCs must start now to plan ahead and do the right things before they become engulfed in the emerging social changes within the LDCs. Technological changes, on the other hand, are taking place at a much faster pace. This increased uncertainty in the environment of the MNCs also means higher risks and dangers of extinction for those companies whom are not innovative and those slow to adapt.

Strategic planning evaluates the mission of the organization, its objectives, and possible actions given the environment. Strategic planning is not restricted to long-range plans but also consider short-term tactics. Furthermore, the aim is not to reduce and eliminate the risks associated with technology transfer, but to rather recognize risk and aim at taking advantage of the rewards the risk might offer. Figure 3.10 is a simplified systems paradigm for technology transfer. It is not a strategic flow, and responsiveness to the environment is accommodated through the presence of feedback loops.

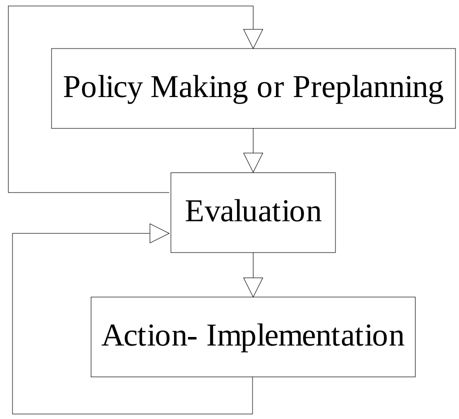

Figure 3.10. A Simplified Paradigm for Technology Transfer [7]

3.4.2.1. Policymaking or Preplanning

The policy maker initiates the technology transfer process by first identifying the development problems that need to be solved. He also identifies the stakeholders who are capable of solving problems initiated by the ministry or department of planning and development in the respective LDC. Free enterprises are not the rule in LDCs [7]. The public sector has a greater role to play in supporting and encouraging entrepreneurs until the private sector is able to initiate such processes independently.

The "active" participants identified by the policy maker planners are referred to as stakeholders [7]. They are groups or individuals whose actions and activities are likely to influence the technology transfer decisions. The policy makers also have hierarchies for the different social and economic problems afflicting their country. It must be decided which of these are presently and primary concern and should be readily addressed.

The needs derived should also pay attention to the LDC's culture and value system, the availability of resources, socio-economic factors, and the ability to afford [7]. The stakeholders therefore identify the strengths (Such as raw materials, the availability of a labour force, responsiveness to the environment, or low cost of production) and weaknesses (Such as lack of support services like fire protection, ineffective communication system, poor transport networks, underdeveloped related industries, poor supplier chain, and lack of skilled labour force in management and engineers) of the country given their needs.

The stakeholders also have to identify the different technologies available to satisfy the LDC's needs given their capabilities and limitations [7]. There should also be a screening procedure in place to narrow down this long list of alternatives.

3.4.2.2. Evaluation

Due to "bounds of rationality" on human judgment, it is difficult to comprehend, analyse compare, and contrast several alternatives at a time and still be consistent in our judgments. One approach might be to use statistical analysis in determining which of the technology types are more significant in achieving the LDC's goals and objectives. The narrowed list can be offered for further analysis. Then one of the following decision making models [7] can be used to take a decision.

- Nominal Group Technique
  Groups work in a structured environment with strict control over discussion. Decisions on which technology to transfer will be based on ratings by group members.

- Stakeholder Analysis/Cooperation
  The decision-maker resorts to an innovative approach to manage change by including stakeholders in the decision-making process. Recommendations made by the interested groups will be used to derive a final decision.

- Scenarios
  Various environmental conditions that may influence the decision are specified. The most probable future condition are stated and used as the basis for making the final decision.

- Delphi
  Judgment of external experts on probable events and responses are used. Their innovation can be used as a basis for selecting the appropriate technology.

- Social Judgment Analysis (SJA)
  Those affected by technology transfer use different judgment processes `to arrive at a conclusion. Group members study the logic behind these judgments and a consensus for resulting decisions is arrived at.

- Morphology
  Technology transfer in composed of a number of factors, which need to be integrated into the overall decision-making process. The decision-maker acts on these to derive at a conclusion.

- Analytic Hierarchical Process (AHP)
  This requires the development of priorities for the different technologies based on the decision-makers judgment. The appropriate technology is selected, based on a quantitative solution to these rankings.

- Optimisation
  Though difficult to achieve the technology transfer-type environment, it can be applied at a micro level for the allocation of limited resources.

- Simulation
  Experimental analysis uses a prototype model to test the effect of the technology and how it can enhance the LDC's development objectives.

3.4.2.3. Action-Implementation

The action-implementation process includes setting goals and verifiable standards to measure the success or failure of the technology transfer process. The standards are necessary to ensure that the desired goals and objectives of the LDC are continually being satisfied. A Modified Relevance Tree Diagram (MRTD) [7] is used to present the LDC's mission, objectives, constraints and standards. An example of such a MRTD is shown in Figure 3.11.

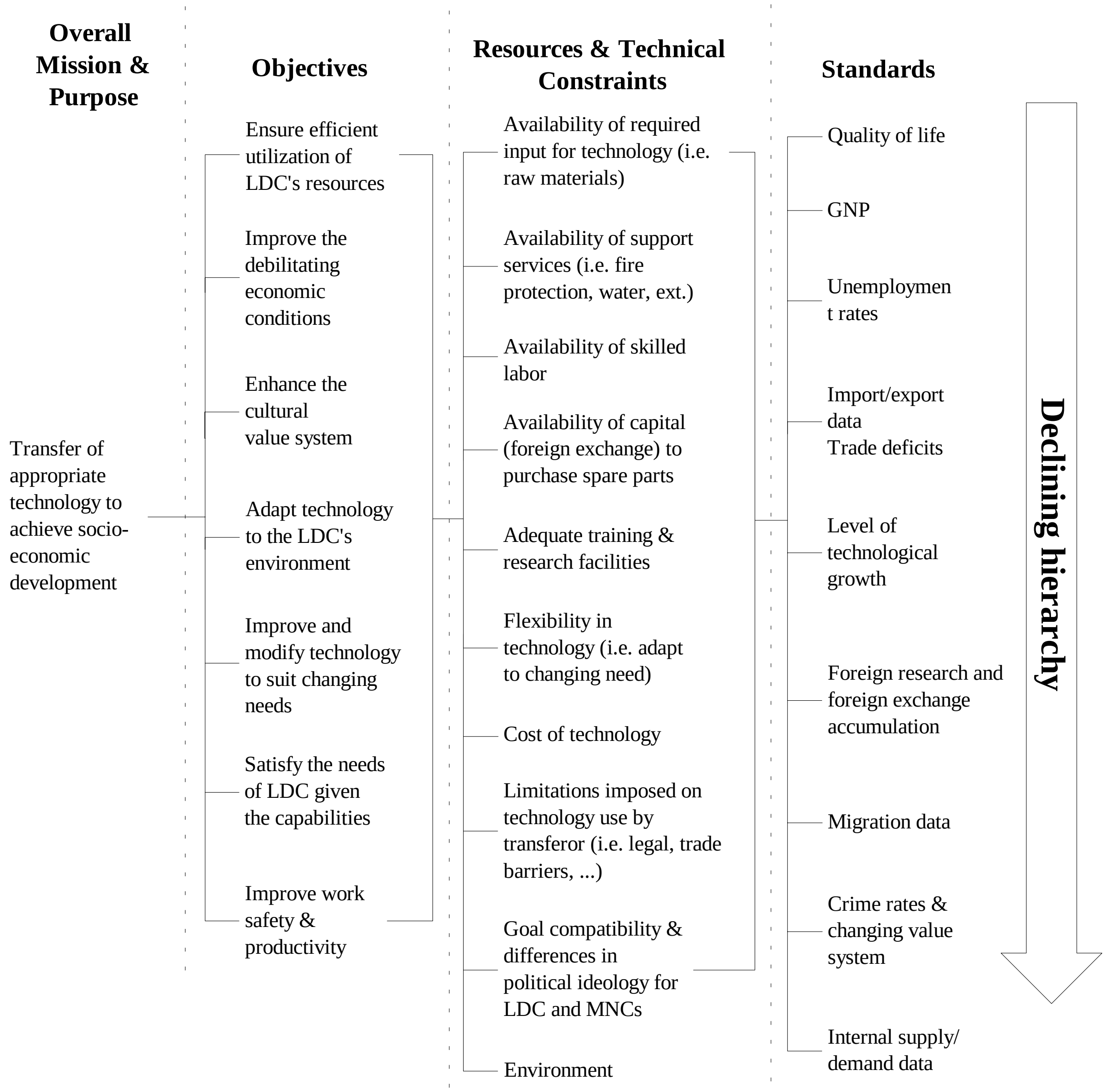

Figure 3.11. A Relevance Tree Diagram for Transfer of Appropriate Technology

Although it is seldom possible to control the external environment factors, proactive strategies may be developed to anticipate them and contingencies developed for dealing with them in the event they might occur. This is why the environment is included in Figure 3.6 as a limitation.

Standards as presented in the MRTD cover measures for both social and economic growth. It is imperative that appropriate support systems be in place before technology is transferred. This implies the extension of the planning horizon of the technology transfer process in order to develop these supports. Awareness programs should be developed to acquaint the LDC's citizens about the role of the technology in improving their quality of life. This is vital to ensure their support in the successful implementation of technology [7].

Governmental restrictions may impose constraints on a new technology, even when the technology may be appropriate. It is still necessary to appraise the technology on such scores as reliability, dependability, maintainability, efficiency, aesthetics, and safety [7]. Although it may seem more rational to seek the best quality, it may not always be the desired choice for the LDC given its economic limitations. It is therefore, the ability to afford that will determine the level of technology transfer. Technological growth and advancement should follow a gradual process. The focus should be first to satisfy the local market and then to gradually penetrate the international market [7].

Quality of Life

In evaluating the nations performance, GNP does not take into account social costs due to industrial waste, crime, congestion, and different perceptions of the inhabitants about their changing environment [7]. A more integrative index is needed to consider both the economic as well as the social performance of a society. The cost-benefit approach will expand the LDC's worldview and potentially reduce the probability of transferring inappropriate technology.

In most LDCs productivity is low and the transfer of technology may not easily improve it. Automation and high technology may not be the answer to the declining productivity in the case of LDCs. The living standard in LDCs is low, malnutrition persists, and diseases like malaria and AIDS incapacitate the working force leading to the decline in productivity [7]. Successful technology transfer requires the existence of critical inputs such as skilled labour force and effective management [7]. However, to improve productivity, the quality of life in the LDCs needs to be improved.

Many may assess the success or failure of the technology transfer process by evaluating only the LDC's economic indicators like GNP. Much of the country's population continue to reside in the rural areas where statistical data are often very difficult to obtain. Many of the economic transactions such as trade by barter and exchange of goods (i.e. food) for services are often intractable and almost never show up in the government records [7]. Thus, economic indicators are inadvertently misleading.

There is therefore a need to consider the importance of human and political factors in development problems, the uncertainties in the decision-making environment, the shortages of data and skilled manpower, and the large communication gaps between different groups in any approach to solve development problems. The appropriate development models should have the following [7]:

- Build in flexibility.

- The capacity within organizations to collect the data and carry out studies themselves.

- Encouragement for grass roots participation in problem definition, data collection, and implementation.

These attributes are percent in the quality of life index as a measure of socio-economic and technological progress. Mankind is increasingly becoming aware of his natural environment and actively protesting to prevent its blatant destruction. These attempts are aimed at improving his quality of life as he realizes that there is a serious trade-off between economic and social development. Both economic gains and social costs associated with technology are analysed better through the use of more integrative methods such as the quality of life index [7].

A systems detailed paradigm for technology transfer is shown in Figure 3.12 and makes evident the fact that technology transfer is an ongoing process which is continually dependent on information flow on the performance of existing technology

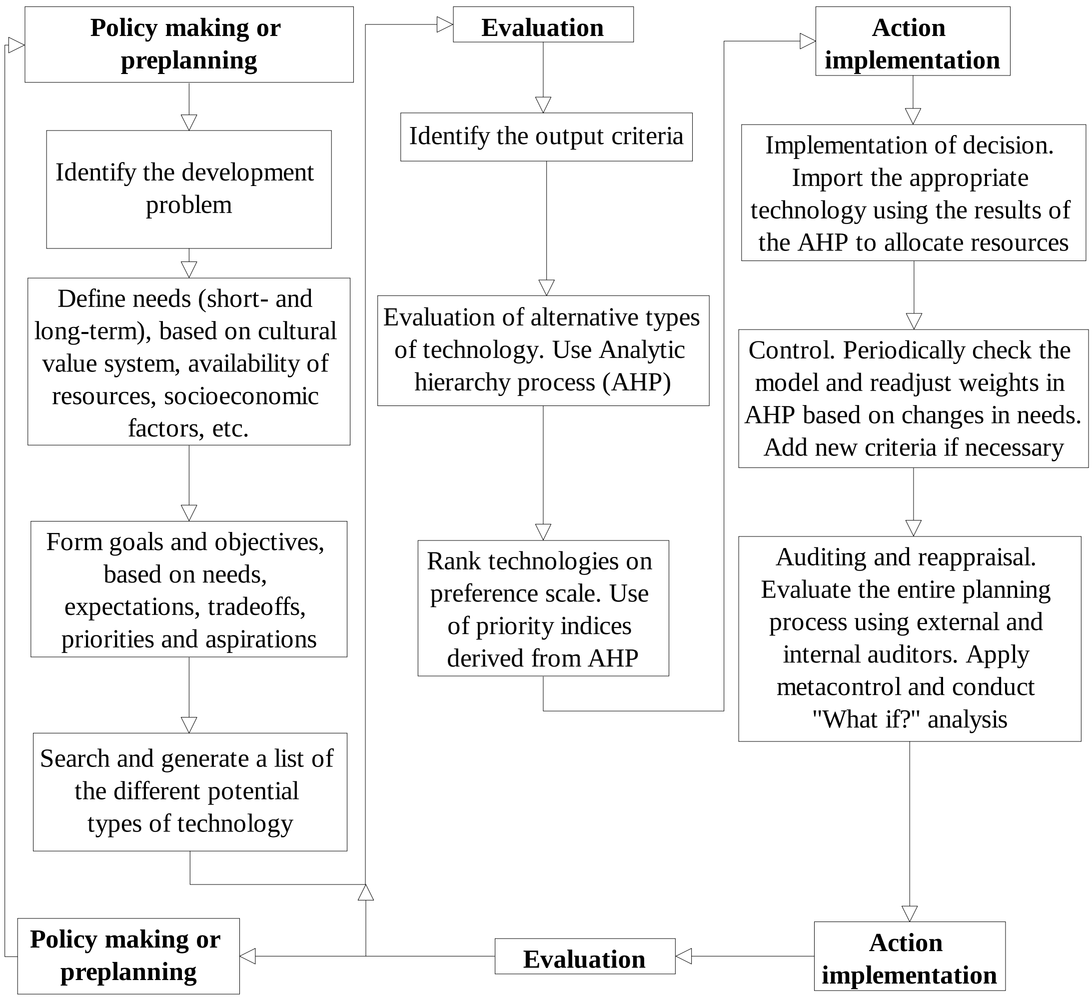

Figure 3.12. Systems paradigm for Technology Transfer [7]

3.4.3. Strategic Planning Dialectical Approach

The increased importance of the political aspects in decision-making has brought to light the role of cognitive factors in strategy formulation. Overemphasis is placed on the economic implications of technology transfers [7]. While economic issues are important, they are effectively addressed only when a wide range such as cultural, behavioural, structural, and political aspects are integrated into the decision-making process. To successfully benefit from these collective efforts, we must understand the cognitive differences between the transferor and the transferee of technology [7]. In group-decision-making participant's psychological attributes differ and influences their decisions. The chosen plan is based on the decision makers' perspective of reality, which differs since the transferor and receiver have different experiences, cultures, value systems, needs, and capabilities.

Through the formation of coalitions, stakeholders who may share different worldviews are brought together in order to analyse and solve the technology transfer problem. The uncertainties in the decision are reduces if the stakeholders understand each other's perspectives.

Achieving reasonable compatible goals between multinational corporations (MNC) and less developed countries (LDCs) will lead to synergistic effects and further progress in the transfer of technology. Dialectical inquiry system (DIS) can be applied to demonstrate decision-making problems [7]. It recognizes the different worldviews of decision makers making it pertinent for use in complex decisions such as technology management. DIS involves examination of the assumptions underlying an expert's proposals, the negation of these assumptions, and the development of the counterproposal based on the negated assumptions. Through theses and antheses, syntheses may be achieved which will benefit the participants in technology transfer. Some technology transfers have failed due to poor management and implementation. By using DIS, the decision makers can consider several alternatives and plan for the transfer.

Figure 3.13 represent in a diagrammatic format the needed path to follow to reach goal compatibility between the LDC and the MNC. Each step in the Goal Compatibility concept diagram will be briefly discussed.

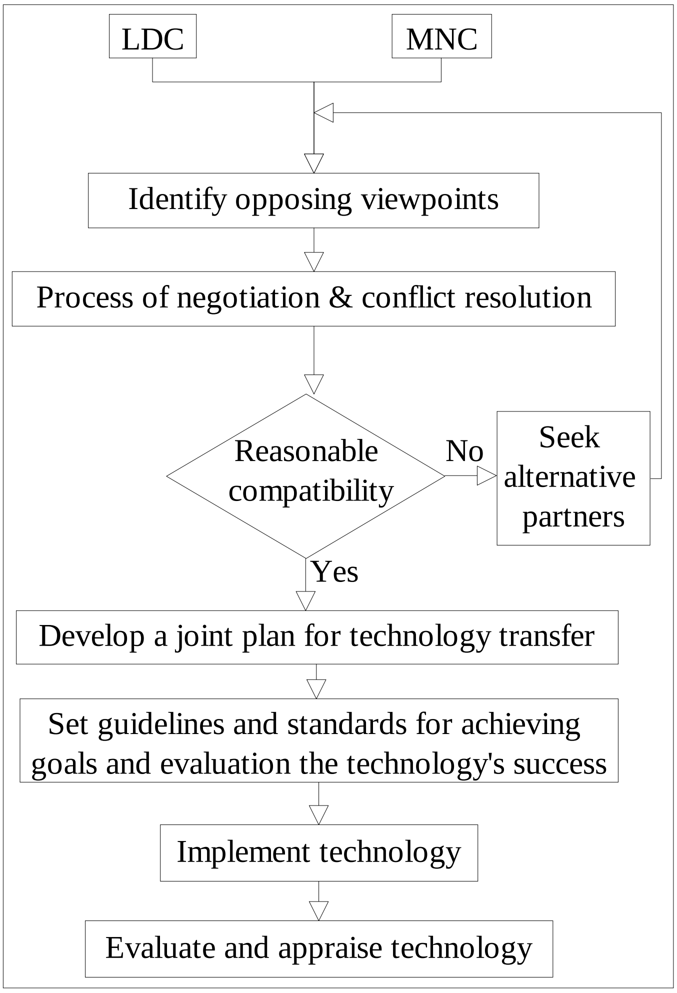

Figure 3.13. Goal Compatibility Concept using Dialectical Approach

3.4.3.1. Identify Opposing Viewpoints

Successful transfer of technology requires that both the transferor and the receiver have some compatible goals and objectives. MNCs are profit-making institutions while LDCs' governments are non-profit and concerned with social gains. This alone is enough to produce incompatible goals.

The need for technology is overwhelming and technology continues to be transferred even in the absence of compatible goals and objectives [7]. Planners in developing countries should have multiple perspectives in order to understand alternative paradigms that may be a function of culture and different worldviews.

LDCs need not to resolve all conflicts in technology transfer. Some conflicts may never be resolved, and might actually be beneficial by serving as a challenge to the system, fostering creativity and innovation [7]. The system should operate within these limits. Negotiations of technology transfer should take into account the different worldviews and the cultural value system that may make it difficult to achieve compatibility. Negotiation processes should therefore accept some conflicts as given, and work within this framework.

The conflict resolution process will not only lead to innovation and change but can also make change more acceptable. The source and intensity of the conflict must however be understood and managed effectively [7].

Figure 3.14 shows the productivity vs. conflict curve that indicate the use and positive side of conflict. With low or no conflict, people become stagnant and the group will deliver limited challenges. More conflict will also be degenerative. People become suspicious and do not trust each other. This then lead to an unpleasant working environment with low productivity. The optimal region of conflict (shaded aria indicated on Figure 3.2) will stimulate innovation, encourage more effective work-performance, motivate a search for effective problem solving, and give a better change adoption. This region is found just to the left of the maximum productivity point. The reason therefore is that once a firm has had too much conflict, management will have difficulty getting back to the, more desirable left side of the figure [41].

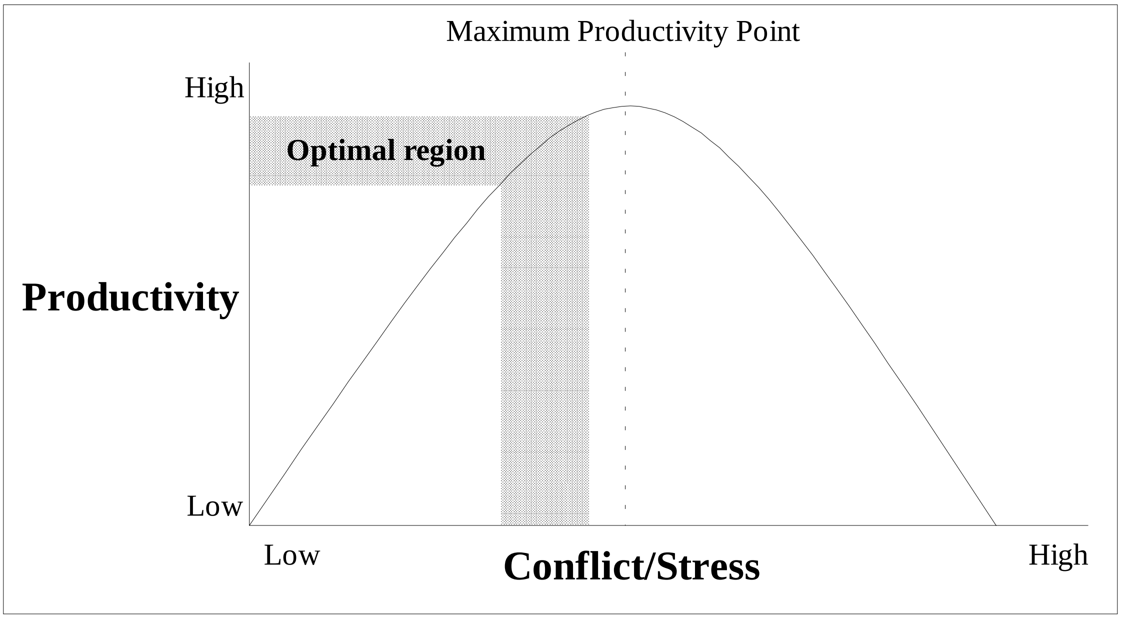

Figure 3.14. The relationship between productivity and conflict/stress [41]

3.4.3.2. Negotiation and Conflict Resolution Process

The MNCs may require some stability assurance in terms of political stability, public policies (such as taxes, foreign exchange, regulations, or import/export restrictions), and so forth. On the other hand, the LDCs will want to know about legal constraints limiting the extend of technology utilization, pollution that may be associated by the technology, training of the LDC's nationals, the availability of limited patents for producing technology, the limitations on exports, the cost of purchasing technology, the conditions for purchasing spare parts and of getting equipment maintenance, and the possibility for developing appropriate research.

The process of negotiation aids in establishing a communication pattern between the LDC and the MNC. Through effective communication, the goals, objectives and aspirations of both parties become clear. Thus, effective communication is invaluable for the effective transfer of technology [7].

There are a number of different ways [41] to deal with conflict and these could also be combined to form an approach. The different ways are:

- *Avoiding* - Ignore the conflict. It will resolve itself.
- *Resolving* - Integrate differences and hit upon a compromise.
- *Higher goal approach* - Identify higher goals that both parties have in common.
- *Restricting\Limiting* - Well structured interaction and communication, with a time limit and informal discussion about conflict. Involve a third party if necessary.
- *Confrontation* - Integrated problem solving. Plan interaction and search to find compatible goals. A consultant or third party may be used with complicated situations involving large groups. There shouldn't be too much emphasis on a time limit with an instant solution. A mutual minimum amount of trust must exist.

Figure 3.15 [41] gives a graphical presentation of possible strategies that could be followed with regard to ones orientation towards self-reward and cooperation.

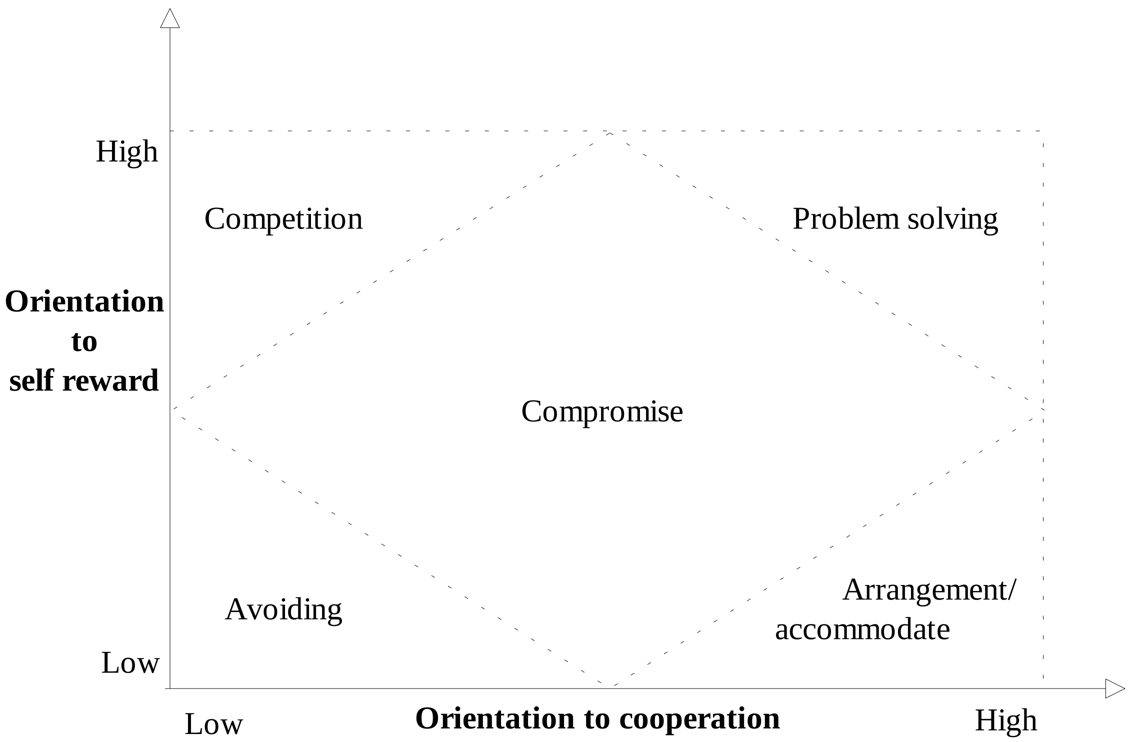

Figure 3.15. Possible strategy to resolve conflict [41]

3.4.3.3. Development of a Joint Plan for Technology Transfer

A plan is developed with a set of guidelines and standards on how to transfer technology. This plan should include timetables for transfer and the sequence of transfer, education and training of the local workforce, development of the local management process, implementation phases and resource requirements, a program for R&D, and plant location sites [7]. The guidelines and standards are control measures for assessing the success or failure of the transfer.

Technology transfer to the LDCs nowadays often take place with ever more complicated arrangements with the technology seller. For example the Algerians have increasingly sought to transfer technology through, what they call, clef en main, produit en main, and marché en main [42]. These arrangements mean:

- ***Key in hand (Clef en main)***
  Here the technology supplier's involvement continues past the point of completing the production facility to the training of staff.

- ***Product in hand (Produit en main)***
  Produit en main transactions are not complete until the facility is fully operational and has delivered products for an extended time.

- ***Market in hand (Marché en main)***
  In the marché en main arrangement, the technology seller provides both the produit en main service and a guaranteed market segment.

3.4.3.4. Implementation Of The Technology

Implementation can be "incremental" of "whole". With the "incremental" approach the technology may not be introduced all at once. This often occurs while the critical capabilities such as labour, natural resources, or capital, are inadequate or lacking [7]. The "whole" technology concept requires that the company is sufficiently capable to provide the needed critical inputs. A country can progress from an "incremental" to a "whole" concept if their capabilities are improved.

The implementation of technology also implies the existence of some support systems, such as a trained workforce, an infrastructure (transport, communication, energy), and the support of the LDC as well as the MNC, in order to achieve success. The implementation approach itself should be one of gradual nature and not drastically forced onto society. This will assist in acceptance, which is needed for success and avoid rejection.

3.4.3.5. Evaluation and Appraisal of Technology

After achievement of short-term goals, the technology can be upgraded to a more advanced technology. However, the upgrading of technology requires that the recipient is capable of sufficient innovation and R&D [7]. The MNC has a role to play here by integrating its technical staffs, which are nationals of the LDCs in the R&D decision-making process. These people have working knowledge of the culture, socio-economic, and political systems of the country and will help the MNCs in developing appropriate technologies.

MNCs should therefore adapt an environmental/institutional strategy to adapt to the changing needs of LDCs.

Enthalpy and Entropy Cycle

The dominant economic, social, cultural, psychological, and political forces of a LDC also influence the direction of technological change. Enthalpy is achieved when growth occurs or there is progress, while entropy is the result of societal decay or decline [7]. In whatever state the country might find itself, it must work towards progression. Enthalpy and entropy are achieved at different levels and could also be defined for a company. The difference between enthalpy and entropy can be given as:

- ***Enthalpy***
  Enthalpy is achieved when appropriate technology is transferred, pollution is controlled, social responsibility is maintained, planning and implementation is achieved, and the recipients are able to achieve technological independence and sustainable development.

- ***Entropy***
  Entropy can come as a result of the transfer of inappropriate technology, incompatible goals of LDC and MNC, or poor planning and implementation.

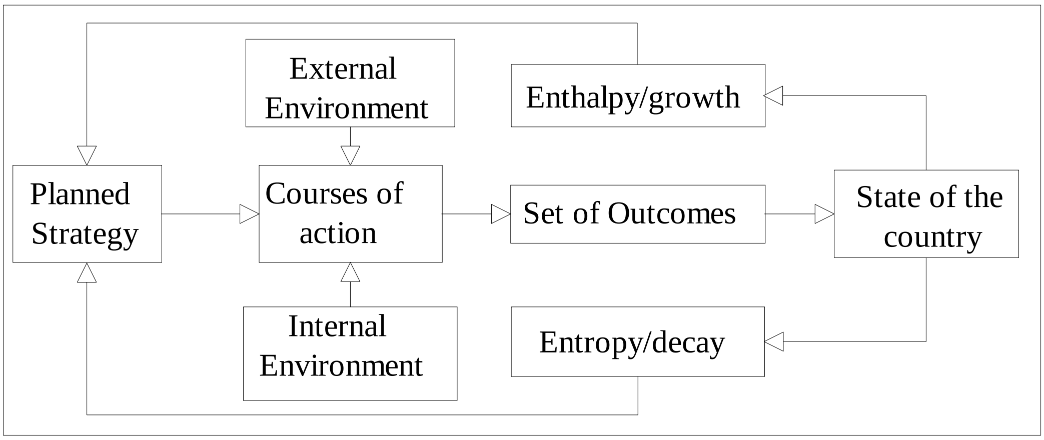

Figure 3.16. Strategic Planning in Technology Transfer [7]

Each arrow in Figure 3.16 indicates, that the object at the beginning of the arrow has an influence on the object at the end.

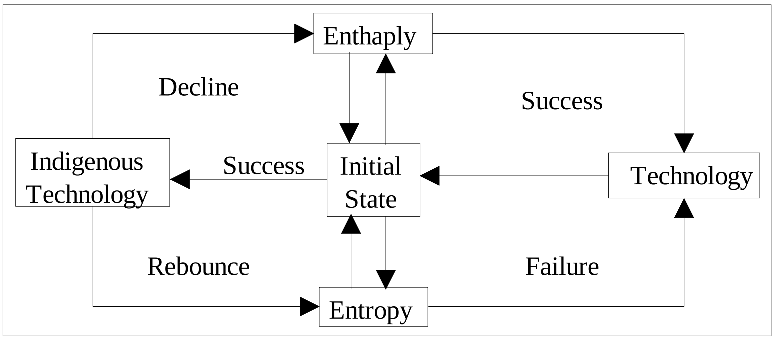

Figure 3.17. The Enthalpy and Entropy Cycle in Technology Transfer [7]

The Enthalpy and Entropy Cycle in Technology Transfer is a dynamic system. Success of technology transfer may also lead to development of indigenous technology that can lead to further growth, but might also cause decay. A country finds itself thus in an initial state and through either the indigenous- or the foreign technology can it drift towards enthalpy or entropy. The cycles are presented in graphical format in Figure 3.17 [7]. In Figure 3.17 one can see 4 different cycles that could be caused by technology. Two cycles are indigenous technology, and the other two foreign.

3.4.3.6. The Six Principles of the Dialectical Materialism Inquiry System (DMIS)

DMIS deal with the field of policy and strategic planning from a holistic systems and dialectical point of view. Six principles of DMIS, which can enhance the technology transfer decision-making process, are: the principle of change, contradiction (Unity and Conflict of Opposites), transformation of quantity into quality, totality and interconnection, negation, and praxis. The six principles of DMIS lay much emphasis on change as an important phenomenon, which must be anticipated and planned for if technology transfer is to succeed. This will facilitate making quality decisions. The six DMIS principles are discussed briefly [7].

1. ***The Principle of Change:*** The LDCs seek technology to improve their economic well-being and enhance their development programs. Change may be the only solution to the numerous economic problems facing them. With technology, different needs and opportunities are likely to emerge and people’s perceptions and values are often changed. The cumulative effect will be a change in the social and economic structure of the country. What is needed is knowledge about how to manage change. Change can be managed through appropriate education, training, and awareness development programs.

2. ***The Principle of Contradiction (Unity and Conflict of Opposites):*** The socio-economic system might reveal political instability, high unemployment, a poor standard of living or quality of life, or other problems. The culture value system may also show strong attachment to families, a commitment to the preservation of nature, rejection of new and foreign technology, inadequate motivation, and other qualities. The socio-economic needs may thus operate in contradiction to the culture value system, where different cultures exist. LDC’s governments might be willing to operate at an economic loss as long as its social goals are satisfied. MNC,

on the other hand, are profit orientated. This creates contradictions and has to be resolved.

3. ***The Principle of Transformation of Quantity into Quality:*** Entropy will lead to social decline, possibly as a consequence of a misinterpretation of knowledge, poor planning and implementation of technology, or as a result of inappropriate technology. As growth continues, the receiver develops some of the capabilities (human resources or capital) that might have been lacking initially. When a threshold level is reached, a diminishing marginal return effect may occur. Increments of more resources might not necessarily yield the quality and quantity desired. Per capita productivity might decline and there might be a need to automate and upgrade existing technology.

4. ***The Principle of Totality and Interconnection:*** The systems approach will allow the planner to view his/her system as a subsystem of a larger system. With this mode the interaction with other systems can be studied. Systems approach further allows the decision maker to consider all possible that might influence the technology transfer decision-making process. Technology transfer decision-making should consider all the components of the society (social, political, cultural, and economic system), and also the capabilities and possible capabilities of the country (human- and natural resources, and capital) before contemplating a possible joint venture with neighbouring countries of MNCs.

5. ***The Principle of Negation:*** The satisfaction of lower needs can generate new and possibly higher needs. Technological changes will lead to new assumptions, new needs, and new propositions that might negate the previously held believes and assumptions.

6. ***The Principle of Praxis (Habits):*** Through Praxis we justify technology if it achieves social utility and can be applied in solving social and economic problems. Thus, the interaction between technology, economy, improvement, and social utility can be explained using this principle. The social gains and losses due to technology ought therefore to be considered in determining whether social utility is achieved.

3.4.4. A Systems Approach to the Transfer of Mutually Dependant Technologies

Each LDC must address the following issues: identification of technology to transfer, assignment of priorities to the identified technologies, and technology forecasting [7]. The systems approach to transfer mutually dependant technology address these first two issues. Unlike economic models, which consider primarily quantitative factors, the systems approach integrates behavioural, structural and technological issues in making decisions. When technology is transferred without consideration of all these subsystems, a planning gap is created that may eventually lead to political, economic, and cultural decline.

Mutually dependence means, that some technologies may yield more benefits if there are other technologies in existence to support their activities [7]. LDCs may seek to transfer such interlinked technologies to maximize their social welfare. Although the benefits of such technologies may be apparent, its resources available may limit a particular country.

The systems approach to transfer mutually dependant technology will assist policy makers in LDCs in considering their vital subsystems while making decisions. These decisions include which technology to transfer, the allocation of the country's limited resources to the different technology types/industrial sector [7] in order to maximize social welfare, and the source for the transfer of appropriate technology.

The Systems Approach Framework

The Systems Approach Framework is presented in Figure 3.18 [7]. This approach certainly may not address al the pertinent problems that may be involved and it will not guarantee the optimum solution. However, it does offer an integrative approach to this important problem. If policy makers are conscious of the interdependence between technologies and how such relationships can help in maximizing the efficiencies of their industries, they are more likely to develop long-term policies that will support development of dependant technologies.

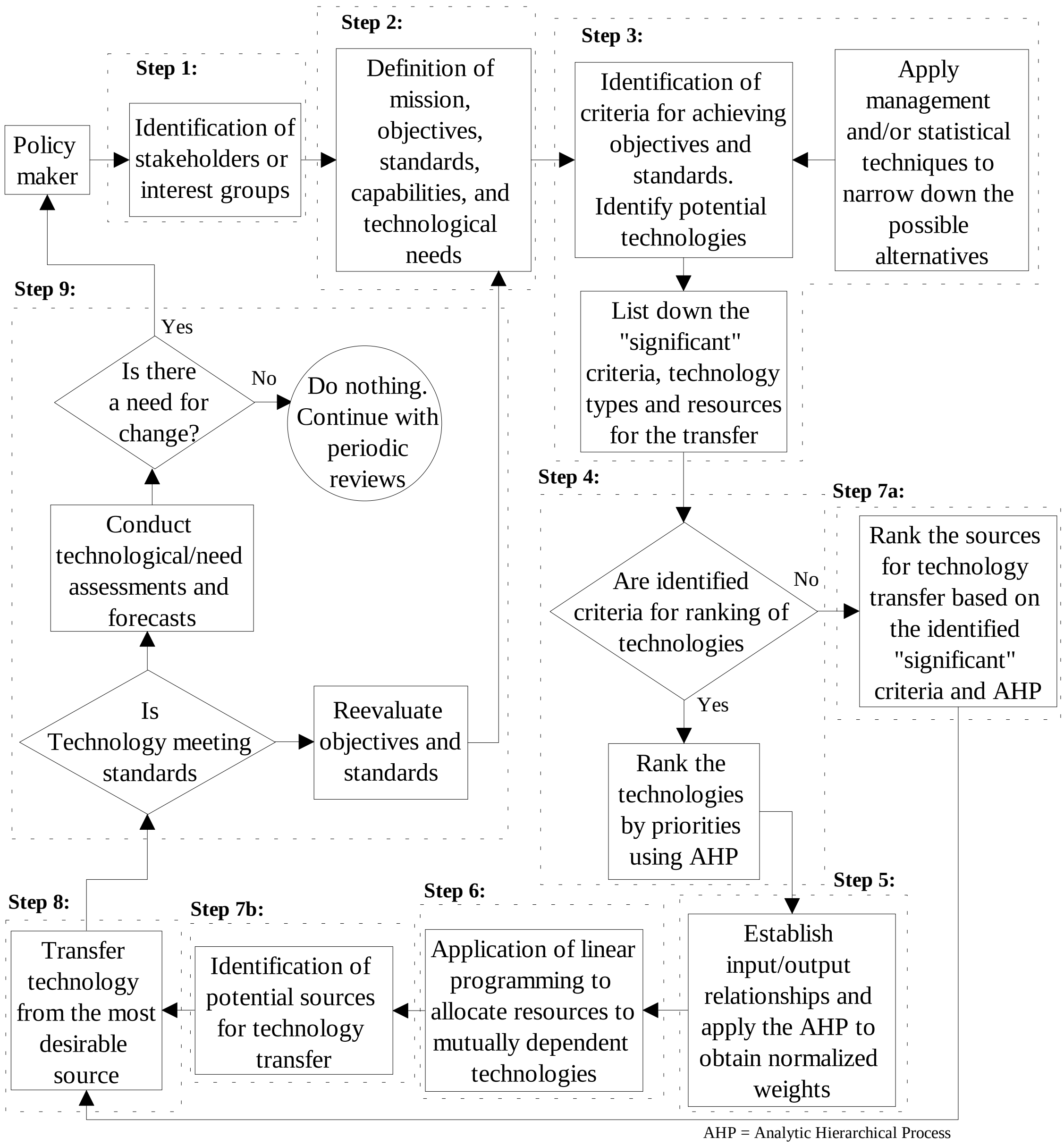

Figure 3.18 A Systems Approach to the Transfer of Mutually Dependant Technologies.

A brief description of the 9 steps in Figure 3.18 follows.

3.4.4.1. Step 1: Identification of Stakeholders or Interest Groups

The policy maker identifies the stakeholders or interest groups whose actions may influence the technology transfer process. A team is then formed to evaluate and recommend the appropriate transfer technology to the policy maker. If the stakeholders participate actively in the technology transfer decisions, the implementation of technological decisions reached by the team will be enhanced.

3.4.4.2. Step 2: Definition of Objectives, Standards, Needs, and Capabilities

The modified relevance tree diagram (MRTD) gives a typical example of the LDC's mission, objectives, constraints and standards [7]. Once the objectives are well defined and all limitations and capabilities well understood set criteria could be established to achieve these objectives.

3.4.4.3. Step 3: Identification of Criteria and Dependent Relationships

A set of criteria for achieving the transfer of appropriate technologies is socio-economic growth, culture value, R&D, resource utilization, cost of technology, and the impact on the environment [7]. The influence of these criteria on technological decisions becomes apparent once the stakeholders express their opinion on how these criteria may influence their social system. There may be different types of technologies which are able to satisfy these criteria and they should be evaluated and decisions then made based on how well a particular technology is able to satisfy these criteria.

3.4.4.4. Step 4: Ranking Technology Types

The essence of considering the different technologies is to ensure that the most appropriate technology is transferred. The analytic hierarchical process (AHP) provides a systematic way to develop priorities for different alternatives based on the stakeholders' judgments [7]. AHP is a multi-criteria decision model that uses hierarchic or network structure to represent a decision problem and then develops priorities for the alternatives based on the stakeholders' judgment.

AHP is used because of a number of reasons briefly described below [7]:

- It's based on pare-wise comparison between competing alternatives which reduces the number of alternatives.

- AHP allows for the consideration of both objective (i.e., cost of technology) and subjective (i.e., culture values) factors.

- Consistency measures are easily derived and used to evaluate the quality of the stakeholders' judgment. Although consistency does not infer quality decisions, however, all quality decisions are consistent. Thus consistency will improve the probability of reaching a quality decision.

- AHP enables people to analyse group decision-making, and arrive at a unique decision that will reflect the opinions of all the participants.

- AHP is an effective tool in arias of management, policy-making, and conflict resolution.

AHP is put into action through a series of pair-wise comparisons between alternative actions or decisions based on a nine-point scale. These definitions are:

Point	Definition
1	Equal importance
3	Moderate importance of one over the other
5	Strong importance of one over the other
7	Very strong importance of one over the other
9	Extreme importance of one over the other

Through the AHP, a factor called consistency ratio (CR) is computed to measure consistency in the stakeholders' judgment. A CR value greater than 0.1 shows that the decision makers were inconsistent. Thus CR<0.1 for consistency.

Example [7]***:***

Geometric mean of weights assigned by the stakeholders						
Technologies	**Mining**	**Agriculture**	**Textile**	**Oil Exploration**	**Information Processing**	**Eigenvectors**
Mining	1.00	0.33	1.00	1.00	1.00	0.153
Agriculture	***3.00***	1.00	2.00	0.50	3.00	0.259
Textile	1.00	0.50	1.00	0.20	2.00	0.120
Oil Exploration	1.00	2.00	5.00	1.00	5.00	0.384
Information Processing	1.00	0.33	0.50	0.20	1.00	0.085

CR = 0.093 < 0.1 Thus consistent.

Table 3.1. Judgment with respect to cost as a goal [7]

Table 3.1 shows the geometric mean of the weights assigned by the stakeholders in comparing the five different technology types on the basis of cost of the technology. Table 3.1 shows for example that agriculture technology has a preference score of 3 over mining technology in terms of cost (indicated in bold in Table 3.1). The scores indicate the importance of the horizontally listed technologies over the vertically listed ones.

It is also important to measure the consistency of the stakeholders. For example, it could be expected that when a stakeholder prefer agriculture technology to oil exploration by a score of 2 and oil exploration to textile by a score of 3, he should prefer agriculture to textile by a score of 6 (2 × 3). The CR (consistency ratio) of 0.093 (smaller that 0.1) indicates that the stakeholders where consistent in their judgment.

The analysis on Table 3.1 was conducted using an Expert Choice program (decisions support system developed to facilitate AHP). The consistency ratio as well as the eigenvector values was calculated within this analysis. The eigenvector values indicate that, in this example, oil exploration is the most desirable technology to transfer when considering cost, followed by agriculture, mining, textile, and information processing as the least desirable technology.

Table 3.1 could be set up for a number of criteria (such as impact on the environment, resource utilization, R&D, impact on culture, and socio-economic influence). A separate table could also be set up which indicates the importance of the different criteria as presented in Table 3.2. For this example, socio-economic is the most important criterion, followed by culture, R&D, resource utilization, environment and cost as the least important criterion (indicated by the eigenvector values).

Goals:	**Socio-economic**	**Culture**	**R&D**	**Resources**	**Environment**	**Cost**	**Eigenvectors**
Socio-economic	1.00	1.00	3.00	5.00	7.00	7.00	0.359
Culture	1.00	1.00	2.00	3.00	5.00	5.00	0.271
R&D	0.33	0.50	1.00	3.00	5.00	2.00	0.168
Resources	0.20	0.33	0.33	1.00	3.00	5.00	0.107
Environment	0.14	0.20	0.20	0.33	1.00	3.00	0.054
Cost	0.14	0.20	0.50	0.20	0.33	1.00	0.041

CR = 0.083

Table 3.2. Judgment with respect to goal comparison [7]

The overall eigenvector priorities are obtained using the eigenvectors in the tables for all the criteria (such as impact on the environment, resource utilization, R&D, impact on culture, and socio-economic influence). This forms a vector matrix α, which is also calculated using the computer software. The α matrix, shown in Table 3.3, implies that oil exploration should have the highest priority, having the highest eigenvector value, for this specific LDC. It further indicates consistency with a CR of 0.06.

Technology	Overall Eigenvector
Mining	0.117
Agriculture	0.181
Textile	0.274
Oil Exploration	0.169
Information Processing	0.259

CR = 0.06

Table 3.3. The α Vector Matrix to indicate overall importance of a technology [7]

3.4.4.5. Step 5: Establish Input-Output Relationships

It is necessary to establish the input-output relationships between different technologies since resources cannot be allocated in terms of priority when there may exist some interdependence between these industrial sectors. Table 3.4 presents the established hypothetical input-output relationships between the five technology types. For example, there is a flow from mining to textile industry while the reverse movement shows partial dependence of the mining sector on the textile industry.

Technologies	**Mining**	**Agriculture**	**Textile**	**Oil Exploration**	**Information Processing**
Mining	1.06	0.11	**1.98**	0.00	0.00
Agriculture	0.22	1.11	0.50	0.00	0.00
Textile	**1.11**	0.76	1.59	0.15	0.00
Oil Exploration	0.26	0.34	0.18	0.15	0.15
Information Processing	0.76	0.89	1.16	1.09	1.09

Table 3.4. Input-Output Matrix [7]

The coefficients in the (i,j) position of the input-output matrix of Table 3.4, is weighted by α_i and α_j and summed over each row to obtain the dependence vector matrix β (Table 3.5).

Mining	0.08017
Agriculture	0.06565
Textile	0.19928
Oil Exploration	0.03431
Information Processing	0.2668

Table 3.5. The β Vector Matrix indicates overall dependence on technologies [7]

The β vector matrix indicates the overall importance of all the technologies in a network where the technologies are interdependent. For this example, Textile technology is the most preferred technology to be transferred and it seems to be the most appropriate technology in this situation.

3.4.4.6. Step 6: Formulate the Linear Programming (LP) Problem

Linear programming is applied to the problem of technology transfer in allocating the LDC's limited resources to mutually dependant technologies. These resources have to be allocated in such a way as to consider all the criteria identified and their respective priorities in maximizing social welfare of the country. The allocation process makes thus use of both the input-output matrix and the priority indices obtained for the technology types. The linear programming problem is then solved using a LP package called Lindo, and given by [7]:

$$\mathbf{Max\ z = 0.08017w_1 + 0.0656w_2 + 0.19928w_3 + 0.03431w_4 + 0.2668w_5} \qquad (3.4)$$

Where the variables w_i represent the ratio of resources allocated to the five industrial sectors, and are upper-bounded by their requirements of the specific resource.

3.4.4.7. Step 7: Deciding the Source of Technology Transfer

The appropriate transferor must share some common goals with the transferee. Different technologies may be transferred from different sources or transferors as each technology poses different constraints. Different technologies may also have different criteria (as indicated in Figure 3.19), which the stakeholders will have to identify and analyse.

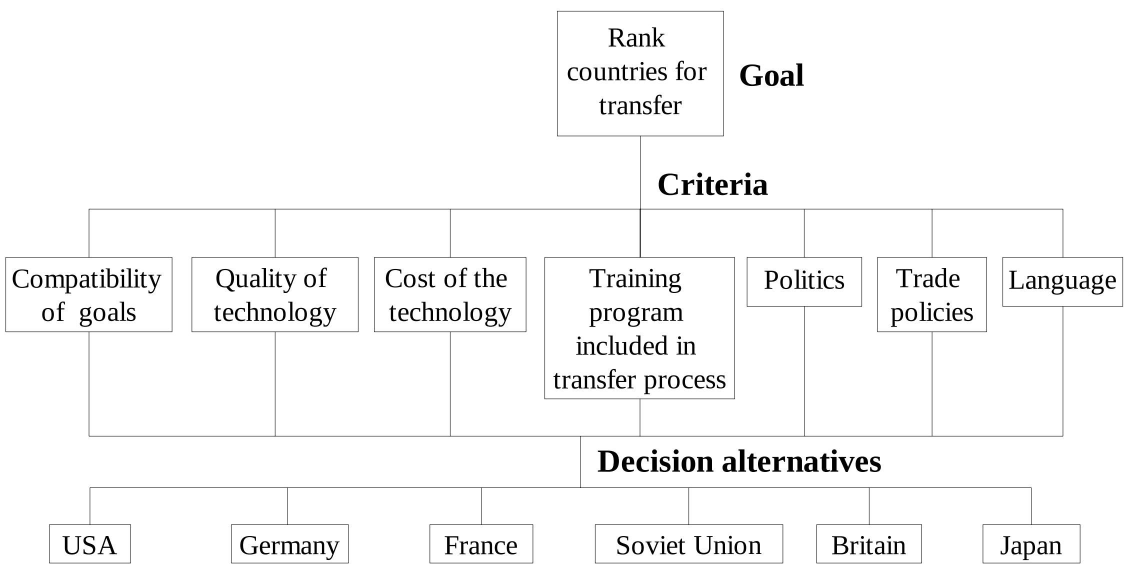

Figure 3.19. A Network Structure for Selecting the Appropriate Transferor for a Chosen Technology [7]

The analytic hierarchical process (AHP) is once again used to decide on an appropriate technology. For each criterion noted in Figure 3.19 there should be an analysis done (similar to the one described in Table 3.1) and their overall eigenvectors once again calculated (as in the β vector matrix in Table 3.5. This analysis will yield a priority matrix indicating the appropriate transferor with the others in declining priority. This might be useful if the most appropriate transferor becomes unavailable due to a specific reason.

3.4.4.8. Step 8: Implementation of Technology Transfer Decision

If the policy maker adopts the group's plan at least to a large extent, the chance of successful implementation is enhanced. The policy maker can effectively argue that all the significant groups participated and adopted the plan. Thus, no particular group can argue that it is not part of this decision process. Since these decisions are based on the stakeholders' consensus, it is possible, but not guaranteed, that these decisions may get the support of the significant interest groups represented by the stakeholders. The approach followed here integrates all the factors, important and influencing the choice of technology.

An incremental approach may be followed in which the basic supporting industries are gradually developed first. The industry least dependent on the others should be developed first [7].

Even when it is possible to create economic motivations to introduce technology, it may be quite difficult to make a switch from the existing practice in an organization. A new technology may be launched quite successfully through dissemination of information about it and through pricing it appropriately, but its success will often depend on its trouble-free performance and reliability. Technology must pass through a learning phase over which the user must become familiar with, and understand the managerial requirements associated with its use [8].

As a new technology is adopted, a backlog of unsolved problems associated with its functioning begins to build up. These problems can be solved only when an adequate number of professionally competent people are available [8], otherwise the pile-up backlog of problems discourages further adoption.

3.4.4.9. Step 9: Control and Technology Assessments

The monitoring process is a form of control to ensure that the country's missions are being fulfilled. Both the stated objectives as well as the standards should be continually re-evaluated. There may be a need to modernize or update the existing technology in anticipation of changing needs. The original standards may also not be appropriate and there will be a need to change [7]. When such needs emerge, the LDC's mission may be redefined, and new objectives and standards established. When the process is operational according to expectations, and there are no new social and economic needs to fulfill, the do-nothing strategy is adopted.

If it is detected that there is a need for change, the policy maker may elect to identify new stakeholders to analyse the problem. These stakeholders also follow the same stepwise approach introduced in Figure 3.18.

3.4.5. The Technology Acquisition Hierarchy (TAH)

The technology acquisition hierarchy model sets three different levels in the technological know-how of the transferor and receiver as shown in Figure 3.20.

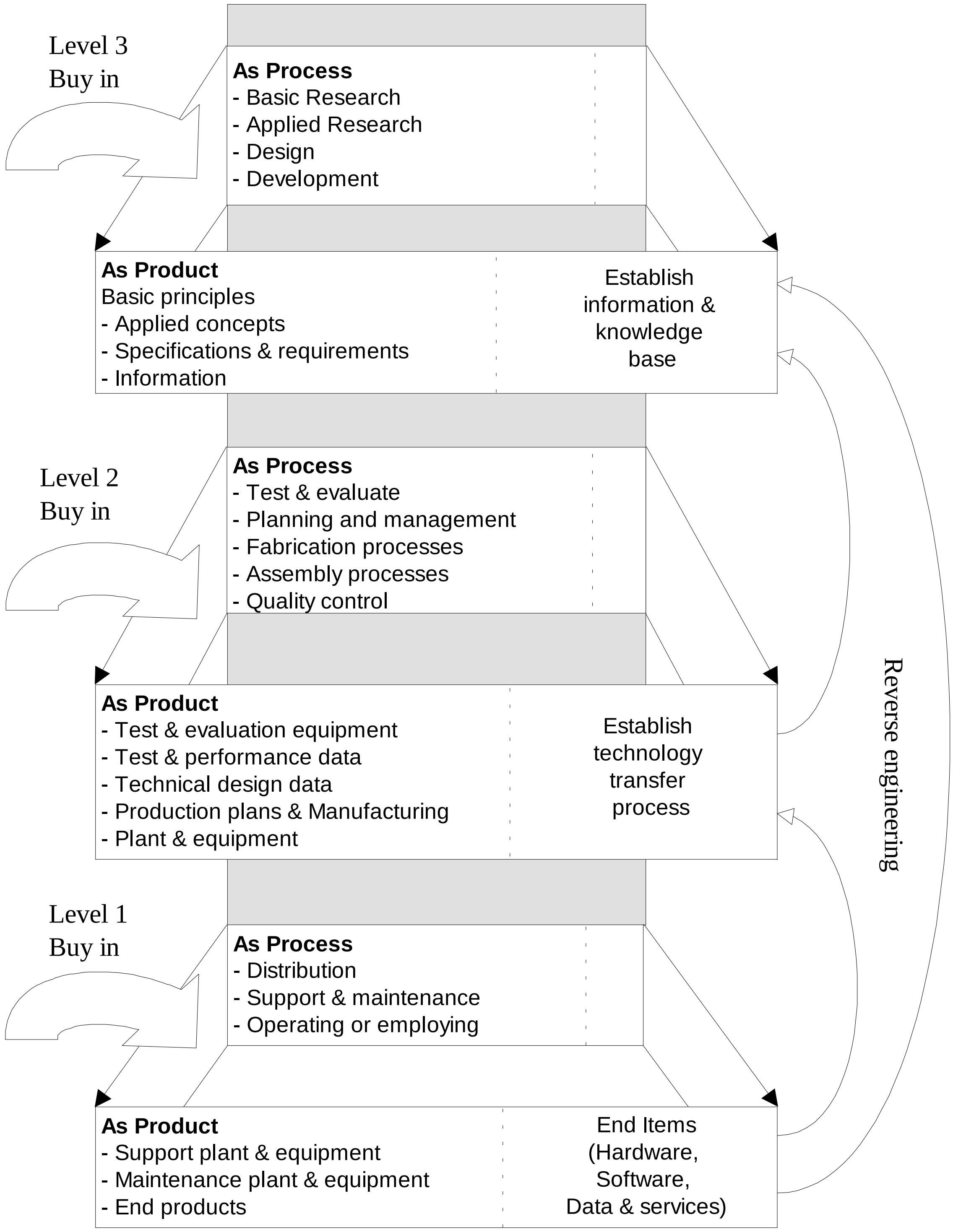

Figure 3.20. Technology Acquisition Hierarchy (TAH)

The basic idea of the TAH is that technology can only be transferred from one party to another at the same level of technological knowledge. The source can supply technology in the form of completely developed product designs to be manufactured by the receiver (level1), transfer of product designs which the receiving country develop themselves (level2), or as research where technology usually flows bi-directional and the receiving country do design and development of products themselves. South Africa is mainly at level one of the telecommunication technology hierarchy when using designs and developed plans from MNCs for production.

In South Africa, more than 80% of the value in industrial business activity is done under (foreign) license [9], and more than 50% of this activity is subject to market constraints. The development strategy followed by South Africa was to educate and develop skills of the human resource appropriately and to create a business environment that made it attractive for MNCs to base a significant part of their manufacturing capability in the country [9]. The later strategy was focused on independence, and were planned to add value at earlier stages of the product life cycle. Industrial growth in the 60's, 70's, and 80's were evolved around the mining and/or agriculture industries. These two sectors dominated the country's development in the transport-, telecommunication-, and energy infrastructure. South Africa should be prepared to cope with the loss in value of natural resources, (such as gold, diamonds, and all the other minerals) which were the traditional providers of economic welfare. The focus should be on "reversed engineering" (also see section 2.5.2. in Chapter 2) and backwards integration along the product life cycle, thereby adding value at earlier stages of the life cycle and gaining ownership of intellectual property. Moving up in the technology hierarchy (indicated on the right hand side of Figure 3.20) provides the freedom to export [9]. South Africa should transfer more technology in the form of design and development, applied research and eventually basic research.

The technology acquisition hierarchy model advises countries not to transfer technology across different technological hierarchy levels. Countries at lower levels do not have sufficient capabilities vested within to productively receive technologies from higher-level countries. The focus is on earlier value addition, self-development, and "reverse engineering" to improve the technological situation.