AN INTEGRATED MODEL FOR TECHNOLOGY ASSESSMENT AND CHOICE FOR RURAL DEVELOPMENT IN DEVELOPING COUNTRIES

Abdallah S. Chungu
Department of Engineering Management and Entrepreneurship, University of Dar-es-Salaam, P. O. Box 350131, Dar es Salaam, Tanzania

Appropriateness of technology has been a long debate in the literature arena. This paper describes the work to develop an integrated model for assessing technologies for specific contextual requirements based on the concept of the appropriate technology developed by the Technology Atlas Team (1987). The integrated model assists also in choosing a suitable technology among a shelf of technologies and goes further to identify the weaknesses associated with the chosen technology before it is put into use. The village level sugar processing technology developed by IPI at the University of Dar-es-Salaam made use of the integrated model to determine the usefulness of the said technology in the respective settings in Tanzania (Chungu et al., 2001).

Keywords: *Integrated model, technology assessment, technology fitness, technology choice, appropriate technology*

INTRODUCTION

The importance of technology choice to developing countries has become a perennial concern of development assistance organizations, international fora, and in the literature. Previous work on the subject of technology choice has provided considerable information on the nature and extent of this process in developing countries. Unfortunately, the need for more information about factors influencing the choice and development of more or less appropriate technologies in developing countries continues to outstrip the ability to provide it. In an analysis of 56 national papers about constraints faced by developing countries for the United Nations Conference on Science and Technology for Development, over 90 per cent of those papers were found to indicate a need for stronger capabilities in the respective countries for evaluating and selecting alternative technologies so that the selected technology would be appropriate (Lucas and Freedman, 1983).

A considerable amount of literature has been published on appropriate technology for developing countries. The term 'appropriate technology' has been interpreted in different ways due to lack of a coherent conceptual framework (Chungu, 1996). The misconception of the term 'appropriate technology' has contributed to the varying degree of difficulties for choosing technologies for development in developing countries. Therefore, clarification of the concept of appropriate technology was found to be a necessity. The Technology Atlas Team (1987), Sharif (1988) and Chungu (1996) have defined technological appropriateness as not an intrinsic quality of any technology, but is derived from the surroundings in which the technology is to be utilised, the objective functions and, in addition, a value judgement of those involved in decision-making in the use of the said technology. Thus, to ensure that the most appropriate technology is chosen, it is imperative that candidate technologies be assessed based on the accepted criteria of appropriateness (Chungu, 1996). Such technology assessment would help to identify possible undesirable consequences resulting from the adoption of a technology and help to choose from among the available technological alternatives.

Chowdhury and Khan (1984) have argued that in using technology for rural development, the choice of technology alone is not enough, its effective utilization is also important. The extent of utilization of the technology by the target group can be improved by taking corrective measures on aspects where there is a mismatch between the technology and the attributes of the target users and the surrounding environment. Information regarding these weaknesses can be obtained through technology assessment. Technology assessment as pointed out by Coates (1974), is a class of policy studies which systematically examines the effects that may occur on the society when a technology is introduced, extended or modified; with special emphasis on those consequences that are unintended, indirect, or delayed. Thus, technology assessment should be made by matching the characteristics of all technologies (traditional and advanced) to the surroundings in which these technologies would be utilised as well as to the purpose of such utilization. Technology assessment therefore is an important tool for the overall management of technology. It can provide valuable information about existing and forthcoming technologies, and thus help decision makers to choose desirable technologies, and avoid selecting undesirable technologies.

Discussions on alternative choices of technologies are largely confined to the choices of technological courses similar to the food menu. Most technology choice models found in the literature focus on the selection of the soundest technology within a group of alternatives. But in these assessment methods, key factors that impinge upon the operationalization of the selected technology are not identified and are consequently not considered. The models found in the literature mostly serve the international technology transfer forum of technology choice. Unfortunately, a systematic model for intra-national technology transfer to rural areas are not offered except for the methodology cited by Sharif and Sundararajan (1984) and a critique made by Chambers (1978) and Baldwin (1983) on cost-benefit analysis. These models however, while meeting their objective of selecting a certain technology, cannot be used to generate information to operationalize the chosen technology. In addition, the models assume that technological alternatives always exist.

The lack of a systematic model not only to identify the intrinsic strengths and weaknesses of a technology but also those with respect to operationalization, give rise to a number of issues regarding technology choice in many developing countries. Tanzania is one of the developing countries in which the issues of technology choice have been highlighted. Some work in this regard has been documented by Chungu (1990), where the lack of fit between the Institute of Production Innovation (IPI) sunflower oil processing technology introduced by the Joint WHO/UNICEF Nutrition Support Programme (JNSP) in 1987 to some women's groups in the Iringa region of Tanzania is highlighted. The women's groups encountered operational problems with regards to using the IPI sunflower oil processing technology. The problems included technical, social, economic, cultural, political, and environmental aspects, depending upon the geographical location of the group. The study concluded that a method has to be found, which could be used to assess factors related to successful adoption and utilization of the oil processing technology in the rural areas. It is however evident that this problem is not confined only to oil processing technology but also to any technology for rural development.

OBJECTIVE OF THE STUDY

As a result of the lack of fit between the Institute of Production Innovation (IPI) sunflower oil processing technology introduced by the Joint WHO/UNICEF Nutrition Support Programme (JNSP) in 1987 to some women's groups in the Iringa region of Tanzania, it was found prudent to mount a study that would investigate the best fit that would benefit all parties involved in the transaction of the said technology.

The main objective of the study was to develop a method to assess technological alternatives and choices in the rural areas of Tanzania. More specific, the objectives were:

(a) Review existing technology assessment methods;

(b) Review existing models of technology choice;

(c) Evaluate the suitability of the existing technology choice models for selecting technologies to be used in the rural areas of developing countries;

(d) Develop a technology assessment and choice model, which is responsive to the objectives, values and surroundings of the user of the technology.

LITERATURE REVIEW

Some of the basic concepts related to technology, technology assessment, technology choice, technology fitness concept, scale ranking and scoring are reviewed.

Definition of Technology

Ramanathan (1994) and Chungu (1996) have analysed in depth the various definitions of technology, and when all the technology definitions are grounded to base, both Ramanathan (1994) and Chungu (1996) found that the technology in its broader definition does consist of four components namely; the technoware (object-embodied form of technology – physical facilities), humanware (people embodied form of technology - human abilities), inforware (documented embodied form of technology - records), and orgaware (institution embodied form of technology - organizational arrangements). Technology however does not operate in a vacuum. Its use takes place within an operational environment called technology climate. The technology climate of a country has been defined by the Technology Atlas Team (1987) as the national setting in which technology-based activities are carried out and includes factors as physical infrastructure; support facilities such as banks, extension services, legal, fiscal, technical workshops, etc.; setting-up of R&D institutions; and political systems at various administrative levels for regulation and facilitation. This broader definition of technology is adopted in this paper.

Technology Assessment

Technology assessment as reported by Martino (1983), can be of three kinds: reactive, corrective, and anticipatory. Reactive assessment is a reaction to currently recognized problems. The objective is to alter the technology, if possible, to prevent further damage. Corrective assessment involves tracing problems to their causes, and initiating research and development before it becomes severe. Anticipatory assessment is concerned with anticipating the future problems, which would be posed by proposed technology. According to Martino (1983), all the three aspects of technology assessment are important. Gotsch and McEachron (1983) have reported technology choice as a problem of choosing from among a set of feasible technological alternatives. Therefore, technology assessment provides the feasible alternatives where a choice can be made.

The frequently used methods for technology assessment as classified by Sundararajan (1983), include general intuitive methods, important component methods, structural decomposition methods, and holistic composition methods. Detailed classifications of some of the popular techniques for technology assessment are presented in Table 1.

Various technological analysts view technology choice models as a device that makes use of technology assessment methods to facilitate the choice of technology.

Technology Choice

Technology choice as defined by Gotsch and McEachron (1983), is a problem of choosing from among a set of feasible technological alternatives. Therefore, technology assessment provides the feasible alternatives where a choice can be made. In many instances, technology choice issues have been looked at from the economist's point of view, taken within the context of the neo-classical model (Stewart, 1972; Stewart, 1978; Uhlig and McBain, 1977; Bhat and Prendergast, 1977; Pickett and Robson, 1977). Two characteristics of techniques have been emphasised – the labour and investment requirements, and the issue is regarded as the one of differing labour and investment intensity. The

Table 1: Classification of popular technology assessment methods

	Classification	Methods	
1.	General Intuitive Methods	(a)	Delphi Technique (Coates, 1974; Martino, 1983)
		(b)	Cross-Impact Analysis (Gordon and Becker, 1973)
2.	Important Component methods	(a)	Checklists (Porter et. al., 1980)
		(b)	Cross-Support Matrix (Hetman, 1973; Ralph; 1973; Guha, 1984)
3.	Structural Decomposition Methods	(a)	Relevance Tree (Coates, 1976; Porter et. al., 1980)
		(b)	Morphological Analysis (Coates, 1974; Porter et. al., 1980)
		(c)	Analytical Hierarchy (Saaty, 1980; Ramanujam and Saaty, 1981)
4.	Holistic Composition Methods	(a)	Cost-Benefit Analysis (Hetman, 1973; Porter et. al., 1980)
		(b)	Scenario Generation (Coates, 1976)

relative costs of labour and investment are regarded as the determinant of the choice. The technology that maximises profit, given the relative cost and is substitutable between labour and capital is selected.

There are many considerations that cannot be taken into account in the neo-classical model which nonetheless have a very significant impact on the choice of technology. As pointed out by Stewart (1978), not all possible techniques available may be known to the decision-maker. Therefore, the decision maker may be unable to choose the technique that maximizes profits. Furthermore, considerations other than maximization of profits may be important to the decision-maker such as easy management, prestige and a desire for modern things (Carr, 1985). Profit maximization as a criterion could also fail to account for services oriented development projects in community-based activities such as health, water, sanitation and education. Baldwin (1983) describes the limitations of the use of present-value calculations in choosing between technological alternatives for rural water supply projects where recurrent (maintenance and operating) costs are high and may be difficult to meet. He states from experiences in Kenya that recurrent resources are more difficult to obtain than capital resources and therefore, argues that the recurrent costs for rural projects should preferably be low. He further adds that, meeting these future costs should be allowed to influence decision-makers and should not be discounted heavily in a present-value calculation. Similarly, Chambers (1978) argues on the wisdom of relying on social cost-benefit procedures when choosing between projects. These procedures, he states, are too complicated and too much subject to personal values and political pressures. He suggests a simpler procedure for poverty focused rural development. The procedure consists of decision matrices, poverty group rankings, checklists and where appropriate, simple listing of costs and benefits, or unit costs and cost-effectiveness. The proposed procedure, according to him, only raises issues rather than having definitive answers.

Delphi technique has been used in India to predict technologies with highest priorities among sectors such as food, health, and energy (Rohatgi and Rohatgi, 1979). A modified Delphi technique consisting of two rounds of questionnaires and restricted respondents only to scientists, engineers, planners, economists and executives within India, was used.

Others have reported the usefulness of the analytical hierarchy approach (Saaty, 1980; Ramanujam and Saaty, 1981). The approach is conceptualised as a multi-objective, multi-criterion problem, where subjective judgements and political processes play key roles. A simplified approach utilising weighing technique was used for comparison by Sharif and Sundararajan (1984). The developed model, which is based on the analytical hierarchy and factor analysis, was demonstrated in Indonesia to choose priority sectors for rural development, and to choose amongst the variety of cooking stoves for three different village settings. In India, Prasad and Somasekhara (1990) have reported an application of the analytical hierarchy process for the choice of telephone technology.

Forsyth et. al. (1980) developed an engineering based index to summarize the opportunities for, and barriers to, substitution of labour for capital in a wide range of industries. He used this index to compare the technology actually used in the manufacturing industry in Ghana, Philippines, Turkey and Malaysia with feasible alternatives.

Bowonder (1979) conceptualised a ranking system, while McBain (1977) used similar ranking method for choosing a footwear technology in Ethiopia. Likewise, Francis and Mansell (1988) have reported to use a similar scoring, in choosing cement technology for Papua New Guinea.

Scoring and Ranking in Technology Assessment

Scale construction yields four types of scales: the nominal scale, ordinal scale, interval scale and ratio scale (Miller, 1983). The nominal scale consists simply of distinguishable categories with no implications of 'more' or 'less' while the position of the ordinal scale can be identified in a rank order with no implication as to the distance between the positions. The interval scale has equal distance between any two adjacent positions on the continuum, and its linear transformation is of the form (Allen and Yen, 1979; Torgerson, 1958):

$$y = ax + b \qquad (1)$$

where a and b are constants, x is the raw score, y is the transformed score, and 'a' must be greater than zero. The ratio scale has not only equal intervals but also an absolute zero, and its linear transformation is in the form (Allen and Yen, 1979; Torgerson, 1958):

$$y = ax \qquad (2)$$

where 'a' is a constant. The level of measurement of the four scales is determined by noting the presence or absence of four characteristics: distinctiveness, ordering in magnitude, equal intervals and an absolute zero. Only the ratio scale, which has all four characteristics, followed by interval scale that lack the absolute zero, whereby, a measurement of zero represents an absence of the property being measured.

Ott (1978) has summarized the shortcomings of aggregation methods for index numbers, and concluded that multiplicative forms were the most common aggregation function. The multiplicative aggregation function "Z" is a weighted product, which has the following form:

$$Z = \prod_{i=1}^{n} Z_i^{w_i} \qquad (3)$$

where,

$$\sum_{i=1}^{n} w_i = 1 \qquad (4)$$

The symbol Π denotes the operation of multiplying together all terms immediately following it and 'w' is the weight for a given term.

The Concept of Technology Fit

Technology fit has been defined by Chungu and Ilangantileke (1992) as a 'fit' between the technology attributes and the user characteristics with respect to using the technology effectively. Chungu (1996) points out that the user is an entity that has certain objectives, values, and specific surroundings. On the other end of the range is the technology, which has certain properties and demands certain requirements from the user. The concept of technology fit is to match the two entities, and see to it that the technology in question would fulfil the needs and aspirations of the user.

The major feature of the concept as pointed out by Chungu and Ilangantileke (1992) is the corresponding pairwise comparison where the technology climate that is required for the successful use of the proposed technology is compared with the technology climate prevailing in the user's location. The pairwise comparison also has to be made with respect to the attributes of the technology in terms of the four components, that is, technoware, humanware, inforware, and orgaware, and attributes sought by the user with respect to the four components. For instance, the technoware of the technology, which is to be assessed, has to be compared with the attributes sought by the user with respect to the technoware. The matching process provides a means to examine the extent of technological gap or fitness between the user and technology. Table 2 shows the fitness scale.

Table 2:.A fitness scale of criteria for assessing the fitness between the technology and user

Scale	Definition
0	No fitness
2	Very poor fitness
4	Poor fitness
5	Acceptable fitness
6	Good fitness
8	Very good fitness
10	Excellent fitness
Intermediate Numbers	In between

Source: Chungu and Ilangantileke (1992)

AN ANALYSIS OF THE TECHNOLOGY ASSESSMENT METHODS

Description of Popular Technology Assessment Methods

One important limitation on technology choice for rural development is the accessibility of information on the different technologies. The technologies available for rural use cannot be identified with all known methods, because the weak communication makes a particular village, ward or district to be only partly aware of the techniques known in the country or worldwide. On the other hand however, techniques may be known but these may not be available because the production of the technology or other inputs required, is not done. This too limits technological choices. Therefore, in an instance where there are no choices, technology assessment should help generate information to best use the only technology for urban and rural development.

The commonly used technology assessment method in rural development is cost-benefit analysis. As discussed in the preceding section, cost-benefit analysis in which attempts to interpret non-economic costs and benefits in pseudo-economic terms, is possible in some situations. However, this is generally difficult, sometimes not satisfying and often quite dependent on the analyst's subjective interpretation of the value structure of concerned groups. Gordon and Becker (1973), Chambers (1978) and Carr (1985), have reported similar views. Another method reported by Sharif and Sundararajan (1984) to be used in rural areas is analytical hierarchy process. The limitations on the use of analytical hierarchy process are presented in Table 3. The remaining methods including also cost-benefit analysis and analytical hierarchy process are widely used in international technology assessment. All these methods however, pose some limitations when applied to the rural context. The pre-requisite of an assessment method for urban and rural development, among other factors, should be simple to be used by district extension officials; save time and resources; take into account all factors affecting technology adoption such as technical, economic, social-cultural, political, and environmental aspects; and also, allow the participation of the user of the technology in the assessment process.

A thorough analysis of technology assessment methods outlined in the preceding section is therefore necessary for a desired rural and urban development. Table 3 provides a detailed analysis of each assessment method. As exhibited, it would not be reasonable to single out one of these methods as appropriate for rural development. Probably the best approach will be an eclectic approach, integrating the merits of several techniques so as to sharpen the reliability of the overall assessment, while minimising the shortcomings discussed in any one method.

Table 3: Characteristics of popular technology assessment methods

Methodology	Application: Suited Best	Application: Level	Limitations
Delphi Technique*	Anonymous individual, scanning, empirical inquiry	All** except group	Consensus tends to stifle minority opinions; consumes time, resource [6]
Cross Support/Tri-Matrix*	Group, scanning, synthetic inquiry	All** except group	Bandwagon effect, loss of face, group biases [2]; lengthy procedures [4]
Cross Impact nalysis	Group, scanning, tracing, synthetic inquiry	All** except group	As No. 2 for [2]; limited interaction [4,6]; marginal probabilities very sensitive [4]
Checklist*	Individual or group scanning, synthetic inquiry	All**	No guidelines, no cause effect linkages [2]
Relevance Tree*	Individual or group, tracing, prior inquiry	All**	Need high knowledge of subject, time, resources [2]
Morphological Analysis	Group, scanning, tracing, synthetic inquiry	All** except group	Obtaining clear problem and parameter identification [2]
Analytical Hierarchy Process	Group, scanning, tracing, synthetic inquiry	All** except group	As No. 2 [2], [7]; complexity and lengthy procedure [1]
Scenario*	Individual, group, tracing, synthetic inquiry, largely qualitative	All** except group	Difficulty in structuring, need high imagination [3]
Cost – Benefit Analysis	Individual, scanning, tracing, synthetic inquiry, largely quantitative	All*	Little consideration of social impacts [5,8,9]; less participation [4].

* Depends on the composition of the experts involved and the relative expertise.
** All level of national, sectoral, village, group.

1. Sundararajan (1983)
2. Porter Ec At (1980)
3. Coates (1976)
4. Guha (1984)
5. Chambers (1978)
6. Kiefer (1973)
7. Prasad and Somasekhara (1990)
8. Gordon And Becker (1973)
9. Baldwin (1983)

Evaluation of the Existing Methods for Assessing Rural Technologies

The evaluations of each technology assessment method to be used to assess technologies for rural areas are presented in Table 4. The scoring in Table 4 is based on the characteristics outlined in Table 3. The Delphi technique is found to be stronger in factor weighting, and the analytical hierarchy method for prioritisation of the evaluation factors, and practicability. The cost-benefit analysis has strengths mainly in time and resources saving. As presented in Table 4, a combination of the analytical hierarchy, Delphi and cost-benefit analysis methods could be used to assess technologies for rural areas. This combination of methods as proposed above is important to remedy the weaknesses of the other. The limitation in each of the chosen assessment method would herewith be discussed.

The analytical hierarchy process is suitable for pairwise comparisons. Its suitability is for processes that may not result into more than the maximum recommended 7 ± 2 technology evaluation factors that it can accommodate at once (Saaty, 1980). The technology when is desegregated, has only four components and thus fulfils the requirements of using analytical hierarchy method. The Delphi technique however, fails to analyse the basis for divergent opinions. Since the technology has been desegregated, the extent of divergent opinions will increase because of increased evaluation factors. Unlike the Delphi and analytical hierarchy methods, the cost-benefit analysis methods on its own, fails to account for much of the socio-cultural factors. Jones (1967) and Rogers (1983) have pointed out the economic factors are not the sole predictors of the rate of adoption of an innovation. Rhoades (1986) has also pointed out that the techno-economic aspects-"are important but they represent only two parts of the farmer's world" meaning that they cover just few things of farmer's perspectives. However, as pointed out by Chungu (1996), the cost-benefit analysis has profound dominance in the first two screening stages, both of which are in the climate assessment. Of course, the cost-benefit analysis was found to be less dominant in the third screening level (the group (user) criteria).

Moreover, these technology choice methods lack the capability to assess and identify attributes needed by the technology to suit the users in rural areas. The information generated would be useful to operationalize the chosen technology. The limitations presented in Table 3 including other limitations that have been narrated above, limit the use of any method in this study. None of these methods would individually meet the requirements for assessing the technology and thereafter facilitating transfer mechanisms. Notwithstanding these limitations, a combination of merits from each method will be important to enrich and build method for assessing technologies in rural areas.

Incorporation of Existing Methods in the Model to be Developed

Though the methods discussed in the preceding section have certain limitations, those methods have also certain strengths. Some features from Delphi technique, analytical hierarchy process, and cost-benefit analysis are borrowed and incorporated in the model to be developed.

The analytical hierarchy process method would be useful for determining the interrelationship among the components of technology for the purpose of prioritisation. The Delphi technique could be used for data collection to feed the analytical hierarchy process. Prasad and Somasekhara (1990) made use of the technique in a similar way. The Delphi technique is also useful for scoring qualitative data. Bearing the limitations narrated in the preceding section, some improvements for the Delphi technique have to be made. Each member of the assessment team would have to assign a score of each factor individually. In case of divergence, the members have to be given the reasons for the divergence. To save time and resources, the process has to be terminated in the second round. Also Rohatgi and Rohatgi (1979) modified the Delphi technique to consist of two rounds. The

Table 4: Evaluation of popular technology assessment methods for assessing technologies for rural areas (indices)

	Methodology	Simplicity to Use	Saving		Evaluation Factor		Prioritisation	Participation /Flexibility	Practice Ability
			Time	Resource	Completeness	Weighting			
1	Delphi Technique	2	2	2	5	5#	3	4	3
2	Cross Impact Analysis	3	3	3	3	3	3	2	2
3	Checklist	3	3	2	5	3	3	4	2
4	Cross Support Tri-Matrix	2	3	3	5	3	4	3	4
5	Relevance Tree	3	2	2	5	3	3	3	3
6	Morphological Analysis	3	3	2	5	3	4	3	3
7	Analytical Hierarchy	2	3	3	5#	3	5#	4#	5#
8	Scenarios	2	2	2	5	3	3	3	3
9	Cost-Benefit Analysis	4#	5#	5#	2	3	1	1	4

cost-benefit analysis as discussed in Chungu (1996), is prominent particularly for the first two screening levels of criteria, that is, the national and user environment criteria.

However, to operationalize the model, ranking and scoring procedures would be needed. In the present study, an attempt is made to compare the state of the technology to be assessed with the status of the location in which the technology is to be used. Thus, the model has to examine the fitness of the technology from the group's point of view. According to Allen and Yen (1979), any scale with the first three characteristics, i.e. distinctness, ordering in magnitude and equal intervals meets the pre-requisite requirement of scoring the fitness of technology with respect to the user (group). However, there are cases in which the preference scale is less or equal to the user's resource endowment, showing that small is better and thus meaning that zero is not an absolute absence of fitness. This kind of preference scale will adopt the interval scale form presented in equation 1. When the preference scale is more or equal to, it stresses that the bigger the score the better, while at the other end of scale, zero represents absences of fitness. The type of scale, which will be adopted in such cases, is the ratio scale presented in equation 2. In summary, two scales of interval and ratio will be used for scoring in this model depending on the nature of the preference scale as required in the appropriateness criteria.

The ranking procedure will adopt the ordinal scale where an ordering in magnitude is needed. The ordinal scale will be used to determine the importance of an evaluation factors as valued by the user of the technology (i.e. the group).

After a thorough assessment of candidate technologies, comparison among technologies is important. This requires the technology to be aggregated again. The role of the aggregation methods becomes evident in this area. Ott (1978) has reported that multiplicative forms of aggregations have acceptance in aggregating decreasing indices. However, the problem at hand, i.e. of fitting the technology with the user surroundings and objectives has a characteristic of decreasing scale. That is, when the scale points zero, poor technology fitness qualities are indicated, and when the scale points far away from zero, good fitness qualities are indicated. Therefore, the multiplicative aggregation method would be useful to aggregate the four components of technology.

The specific technology criterion, which is a focus in the present study, has been developed based on the definition of four components of technology. Therefore, the model to be developed has to incorporate the merits of the existing methods, either in assessing the technology climate or the user of technology (group). The Delphi technique, cost-benefit analysis, and scoring/ranking procedures would be useful for assessing the technology climate. The assessment of the group level with regard to using the four components of technology sought by the group, would need the analytical hierarchy process and multiplicative aggregation methods in additional to the methods used in assessing the technology climate.

DEVELOPMENT OF AN INTEGRATED MODEL

Structure of the Model

This section uses the work of Chungu and Ilangantileke (1992) on the technology fitness concept and the work of Chungu (1996) on developed generic criteria on appropriateness of technology. The integration of the two concepts forms the basic structure of the model to be developed. The development of appropriateness criteria as pointed out by Chungu (1996) were based on techno-socio-economic factors, and this therefore, facilitates the integrated model to assess technologies for rural areas in terms of techno-socio-economic aspects, so that appropriate technologies, which meet the aspiration of the group, are selected.

The integrated model presented in Figure 1, uses the fitness concept and appropriateness criteria, and provides the different screening stages

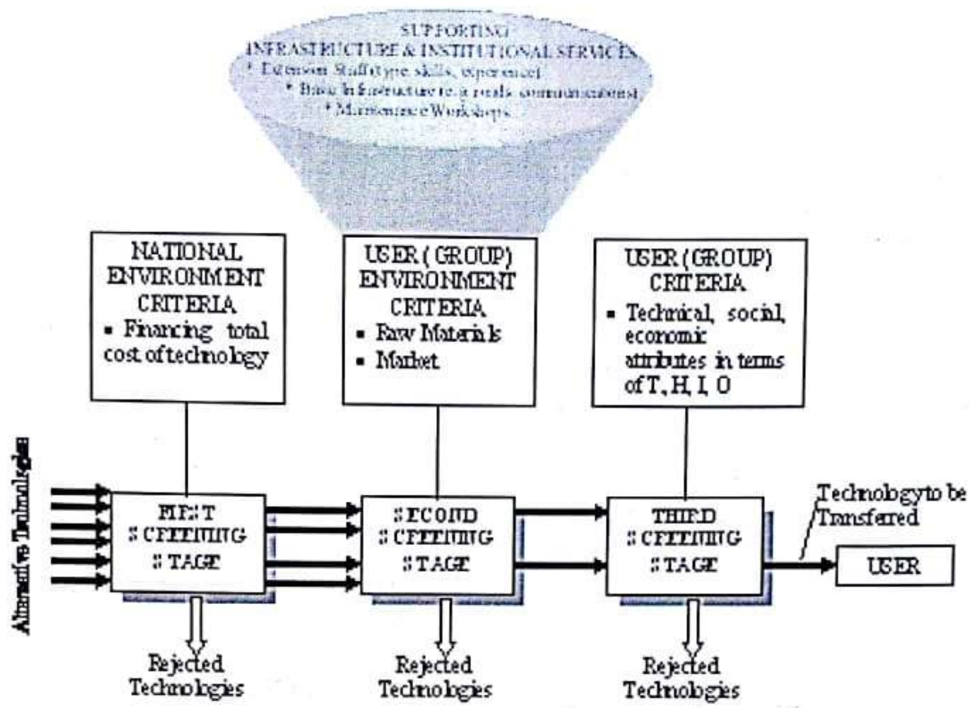

Figure 1: Schematic diagram of integrated model showing technology choice process for a specific technology

consisting of the national environment, user environment and the user him/herself. The fitness process outlined by Chungu and Ilangantileke (1992) is used to evaluate the technological gap in each of the screening levels portrayed in Figure 1, based on the appropriateness criteria developed by Chungu (1996). To assess the level of fitness at each of the screening stages as shown in Figure 1, an index is computed and is called "fitness index". The index computations are discussed separately under the following subsequent section. The computed index would show the extent of the technological gap between the technology and the user of technology (group).

The application of the model starts with the screening at national environment stage. As already pointed out, the national environment criterion is the cost of financing the technology to be acquired by the user (group) in the village, who can be financed by oneself, relatives, villagers, or financial institutions within the village, district, regional, etc. Any technology, which requires financial investment more than what the user (group) could afford in terms of own contribution and the loan accessible to them from the various sources, would be rejected. Changes in financing policies, for instance, provision of grants or loans for dissemination of rural technologies and these funds be accessible by the user of technology, could facilitate the technology to be accepted by this particular environment.

The second screening stage is the user (group) environment that surrounds the user's operations. The criteria for assessing the user environment are raw materials and market size. Technologies that do not meet these requirements of raw materials and market size would be rejected. Changes in the policies with regards to pricing, distribution, production of raw materials, etc., would however, restore the rejected technology to be considered for further screening.

The third screening stage deals with the user him/herself. It takes into account the technical, social and economic characteristics of the group in terms of four components of technology. The socio-cultural issues are left unattended in most assessments. Therefore, the technology, which meets the user's aspirations in techno-socio-economic terms, will be chosen. The remaining technologies will be rejected. Prior to choosing at this level, the opinion(s) of assessment have to be presented to the user(s) and the choice would have to be made by them. At this stage, the choice of the technology is made by insiders, defined as anybody within the users of the technology (group). Figure 1 illustrates that the chosen technology is the one to be transferred to the user. However, the weaknesses in the chosen technology have to be remedied before the technology is transferred.

In cases where there is no technology in the market (locally developed or imported) to meet the needs of the user group, indigenous research institutions are expected to take up the challenge, or related policy measures have to be addressed to accommodate the rejected technologies in the existing market.

Operationalizing the Model

There might be many ways to operationalize the model especially with regard to scoring and aggregation. One way of scoring is to use interval and ratio scales as discussed in the sections. Both processes of scoring the fitness of technology and ranking the weightage of the criteria facilitate a "bottom to top" process. As pointed out earlier, the user ranks the weightage of the criteria. Likewise, the fitness scoring of technology with regard to the user is based on the objective and the surroundings of the user. On the other hand, using the analytical hierarchy process provides the relative importance of the four components of technology. The analytical hierarchy process is applied using the experience of experts in the industry and/or the extension staff in the area. The relative importance of technology obtained using the analytical hierarchy processes are called component contribution intensities (α). Based on these results (α), a multiplicative aggregation method as shown in equation 3 can be used to determine the technology fitness index (TFI) with respect to user. The process therefore allows outside expertise to also contribute to the decision to be made by the user on the subject area. This process is a "top to bottom" approach. The mix of the two approaches of "top to bottom" and "bottom to top" provides a better blend to the model for effective use of the technology for socio-economic development.

Model Operationalization Procedure

A needs assessment has to be conducted prior to determining the kind of specific technologies to choose from. Thereafter, a search of relevant technologies from the so called 'technology shelf' has to take place. The operational steps outlined below have been developed based on the framework and screening processes presented in Figure 1. However, in data collection, one can collect all the data required in the three stages at once. This can save time and resources. On the other hand, the data collection also depends on the extent of assessment required. The resource allocation in the project can be a major factor in determining the extent of assessment. Therefore, the amount of data collected dictates the level of screening that is to be made. As presented in Figure 1, there shall be three assessment levels, the national environment, user (group) environment, and the user him/herself.

The assessment of the national environment

The assessment procedure is as follows:

1. Gather information on the economic situation of the user of the technology in the specified context or village including its surrounding environment for the data that is relevant to the criteria listed in Chungu (1996). Translate the criteria into checklist for ease of data collection;
2. Gather information of total technology cost for each technology under consideration. Such cost will include investment and operational costs;
3. Make corresponding pairwise comparison of total technology cost with respect to the amount that the user could afford (in terms of their own finance and acquired loan). Use the scoring procedure as illustrated in the following subsequent section;
4. Compute the state of fitness for national environment. The fitness index of the national environment (F_{NC}) is given by:

$$F_{NC} = \frac{1}{n}\left[\frac{\sum w_j \cdot s_j}{\sum w_j}\right] \qquad (5)$$

where n is the maximum scale score while w_j is the weightage for criteria j and s_j is the j'th fitness score for criteria j.

The assessment of the group environment

The assessment procedure is as follows:

1. Gather information on potential amounts of raw materials and the market sizes available within the village or the context in question. In addition, gather information of the supporting infrastructure and institutional services for the relevant criteria listed in Chungu (1996). Translate the criteria into a checklist or questionnaire for ease of data collection;
2. Gather information on all technologies under consideration for the data, which is relevant to the criteria listed in Chungu (1996). Translate the criteria into a checklist or questionnaire for ease of data collection;
3. Make corresponding pairwise comparison of total technology and the group for each selected criteria. Use the scoring procedure as illustrated in the following subsequent section;
4. Compute the fitness score of resource utilisation for each criterion in the supporting infrastructure and institutional services.

   The resource fitness score for a criterion in the supporting infrastructure and institutional services (s_r) is given by:

   $$s_r = s_k . v_k \qquad (6)$$

   where s_k is criteria fitness score and v_k is resource linkage value ranging from between 0 to 1. The linkage value (v_k) is assigned according to the level of visit frequencies made by the extension staff to the user (group), or the user him/herself reaching the institutional services. The judgement on these visits has to be made by extension staff and also counter checked with the user or group concerned. An activity (criterion) with no visit at all is assigned a value of 0.0. A value of 0.2 is assigned to "low" frequency of visit. A value of 1.0 is assigned as the maximum value for responses of 'high' frequency visits or 'intensive visits' made. The visits that are of 'moderate' nature are given a value of 0.6. However, the basic infrastructure is an entity in the user's environment, which cannot move, and therefore v_k becomes equal to one for all its criteria.

5. Compute the state of fitness for supporting infrastructure and institutional services.

   The fitness index of the supporting infrastructure and institutional services (F_{SIS}) is given by:

   $$F_{SIS} = \frac{1}{n}\left[\frac{\sum w_r . s_r}{\sum w_r}\right] \qquad (7)$$

   where n is the maximum scale score while w_r is the weightage for criteria r and s_r is the r'th fitness score for criteria r.

6. Compute the fitness for the supply of raw materials and market size for the technology. The supply of raw materials and market size could be established empirically as a function of fitness index of the supporting infrastructure and institutional services (F_{SIS}). The fitness for the supply of raw materials (R) could be given by:

   $$R = f(F_{SIS}) \qquad (8)$$

   and the size of the market (M) could be given by:

   $$M = q(F_{SIS}) \qquad (9)$$

7. Make corresponding pair wise comparison of total technology and the user for raw materials and the market size criteria. Use the scoring procedure as illustrated in the following subsequent section;
8. Compute the state of fitness for user (group) environment. The fitness index of the user environment (F_U) is given by:

   $$F_U = \frac{1}{n}\left[\frac{\sum w_g . s_g}{\sum w_g}\right] \qquad (10)$$

   where 'n' is the maximum scale score while w_g is the weightage for criteria g and s_g is the g'th fitness for criteria g. Raw materials and market belong to criteria g.

Assessment of the group

The assessment procedure is as follows:

1. Gather information on the techno-socio-economic situation of the user (group) in the village for the data that is relevant to the criteria listed in Chungu (1996). Translate the criteria into a checklist or survey questionnaire for ease of data collection;
2. Gather information on relative importance of the components of technology (technoware, humanware, inforware, orgaware) as viewed by experts (such as extension staff) in the area regarding the technology user. Make pairwise comparison among the components of technology and formulate a comparison matrix as shown in Table 5 using the procedure of data collection and matrix formulation as shown in Appendix A.
3. Gather information of all technologies under consideration for data that is relevant to the criteria listed in Chungu (1996). Translate the criteria into a checklist or survey questionnaire for ease of data collection;
4. Make corresponding pairwise comparison of the technology attributes and the user attributes for each selected criteria as shown in Table 6. Use the scoring procedure as illustrated in the following subsequent sections;
5. Compute the state of fitness for each component of the technology.

   The fitness index of technoware (F_T) is given by:

$$F_T = \frac{1}{n}\left[\frac{\sum w_t . s_t}{\sum w_t}\right] \quad (11)$$

   where n is the maximum scale score while w_t is the weightage for criteria t and s_t is the t'th fitness score for criteria t.

   The fitness index of humanware (F_H) is given by:

$$F_H = \frac{1}{n}\left[\frac{\sum w_h . s_h}{\sum w_h}\right] \quad (12)$$

   where n is the maximum scale score while w_h is the weightage for criteria h and s_h is the h'th fitness score for criteria h.

   The fitness index of inforware (F_I) is given by:

$$F_I = \frac{1}{n}\left[\frac{\sum w_i . s_i}{\sum w_i}\right] \quad (13)$$

   where n is the maximum scale score while w_i is the weightage for criteria i and s_i is the i'th fitness score for criteria i.

   The fitness index of orgaware (F_O) is given by:

$$F_O = \frac{1}{n}\left[\frac{\sum w_o . s_o}{\sum w_o}\right] \quad (14)$$

   where n is the maximum scale score while w_o is the weightage for criteria o and s_o is the o'th fitness score for criteria o.

6. Using data from step 2, multiply the entries of the matrix made row wise and take its 4^{th} root. Normalize the resulting values to get the component contribution intensities (α). Call α_t, α_h, α_i and α_o as technoware, humanware, inforware and orgaware contribution intensities respectively (Table 5). The 4^{th} root is used because the technology has four components.
7. Compute the technology fitness index (TFI) with respect to the user of the technology by the following equation:

$$TFI = \left(F_T^{\alpha_t}\right)\left(F_H^{\alpha_h}\right)\left(F_I^{\alpha_i}\right)\left(F_O^{\alpha_o}\right) \quad (15)$$

   where F_T, F_H, F_I and F_O are the state of fitness for technoware, humanware, inforware and orgaware respectively, and α_t, α_h, α_i and α_o are components contribution intensities of the technoware, humanware, inforware and orgaware respectively.

Table 6 shows one possible representation of the integrated model at the user level assessment (third level) in terms of the four components of technology and associated equations 11 to 15.

Scoring Procedure for the Integrated Model

The fitness scale has the features of percentage with the properties of registering zero when the fitness is very poor and a register of ten (or equivalent to 100%) when the fitness is excellent. Based on the scale shown in Table 2, a reasonable fitness, which meets minimum threshold of acceptance for criteria, could be that which has a score of five. This scale is purely used for scoring the fitness (s_k) of the technology with respect to the user (group). An ordinal scale will be used to determine the weightage of criteria (w_k). A range between 0 and 5 is used to signify features such as strongly not important (0), not important (1), a little bit important (2), important (3), slightly more important (4), and strongly important (5). However, the rating of the ordinal scale would depend on the dialect of the user (group) so as to accommodate a feasible distinctive range.

Table 5: Pairwise comparison of the components of technology

Component	T	H	I	O	α
T	1				α_t
H		1			α_h
I			1		α_i
O				1	α_o

where α is contribution intensity

The quantitative and qualitative scoring procedures are the two possible ways of scoring a criterion. Some discussions with regard to scoring procedures have already been made in the previous section.

Quantitative Scoring

The discussion regarding the scoring procedure of a criterion as exhibited in equations 1 and 2 are used to operationalize the model in this section. As already pointed out, there are cases in which the preference scale is less or equal to the user resource endowment, showing that small is better and thus meaning that zero is not an absolute absence of the fitness. Based on Table 2, such fitness will be assigned a score of 10. This kind of preference scale will adopt the interval scale form presented as equation 17. When the preference scale is more or equal to, it stresses that the bigger the score the better, while at the other end of scale, zero represents absence of fitness. The type of scale, which will be adopted in such cases, is the ratio scale presented as equation 16.

Therefore, in cases where both the technology and user, provide quantitative data, the score of criterion can be given by the following equations, depending on the preference made by the user for the specific criterion:

1. If the preference scale is greater or equal to the data exhibited by the user, then the score is calculated by:

$$s_k = 5\left[\frac{f_{te}}{f_{so}}\right] for\, f_{so} \neq 0 \qquad (16)$$

where s_k = fitness score for the criteria k

f_{te} = data of the technology for the criteria k

f_{so} = data of the user of technology for the criteria k

If $f_{te} = f_{so}$ then $s_k = 5$; if $f_{te} = 0$ then $s_k = 0$; and if $f_{te} \geq 2f_{so}$ then $s_k = 10$.

2. If the preference scale is less or equal than the data exhibited by the user, then the score is calculated from:

$$s_k = 5\left[2 - \frac{f_{te}}{f_{so}}\right] for\, f_{so} \neq 0 \qquad (17)$$

If $f_{te} = f_{so}$ then $s_k = 5$; if $f_{te} = 0$ then $s_k = 10$; and if $f_{te} \geq 2f_{so}$ then $s_k = 0$.

3. If the preference has boundary limits where f_l is the lower limit for criteria k, and its upper limit is f_u, then the score is calculated by the following equations depending on:

(i) if $f_{te} \geq (f_u + f_l)/2$, then

$$s_k = 5\left[2 - \frac{f_u + f_l - 2f_{te}}{f_u - f_l}\right] for\, f_u \neq f_l \quad (18)$$

(ii) if $f_{te} \leq (f_u + f_l)/2$, then

$$s_k = 5\left[2 - \frac{f_u + f_l - 2f_{te}}{f_l - f_u}\right] for\, f_u \neq f_l \quad (19)$$

However, for all $s_k \leq 0$, then $s_k = 0$ and for all $s_k \geq 10$, then $s_k = 10$.

Scoring Qualitative Statements

In all qualitative statements, a comparison has to be made between the technology and the user of the technology to see whether the minimum

Table 6: The fitness framework for the four components of technology

	Criteria		Technology to be Assessed	Preferred Scale Direction	Group Status	Score		Fitness	
	Generic	Specific				s_k	w_k	F_C	α
T	E_1	$E_{1.1}$ $E_{1.2}$ $E_{1.3}$ . . $E_{1.k}$							
	E_2							F_T	α_t
	E_3								
	.								
	E_k								
H								F_H	α_h
I								F_I	α_i
O								F_O	α_o
				TECHNOLOGY FITNESS INDEX (TFI)					

Where: T, H, I, O = technoware, humanware, inforware and orgaware respectively
$E_1 \ldots E_{k.k}$ = criteria
s_k = fitness score for the criteria k
w_k = weightage for the criteria k
F_C = state of fitness for components of technology (F_T, F_H, F_I, F_O)
α = components of contribution intensities (α_t, α_h, α_i, α_o)

requirement as stipulated in Table 2 is met. Each member of the assessment team has to make an independent evaluation of the event with respect to the data presented. The mean of assessment scores of the team members has to be taken as a score for that particular criterion. If the deviation from the mean is big, the team coordinator has to obtain reason for such deviation. Thereafter the information is fed back to the team members to reassess the event. All data are fed in Table 6 in order to determine the technology fitness index (TFI).

MANAGEMENT OF TECHNOLOGY CHOSEN

A technology fitness index (TFI) as shown in Table 6, will be assigned to each technology assessed. The technology that exhibits higher technology fitness index (TFI) is chosen for that specific user. However, the chosen technology as per Table 6, there shall be certain criteria that will exhibit poor fitness ($s_k < 5$) with respect to the requirement put forward by the user. Those criteria with poor fitness and having relative high importance to the user signify developmental issues that will need to be addressed or rectified before the technology is transferred to the user. Corrective measures may be to change certain attributes or modification of the technology with respect to that issue or change the user attributes, which ever will be easier to implement.

Even if it was the only technology that has been earmarked for that user, for reasons known to the provider, the integrated model has the ability to provide areas of corrective measures before the technology is given to the user. This unique feature of this model achieves signaling those criteria with poor fitness but having higher importance to the user. Such weaknesses will need to be addressed before the technology is provided to the user, for effective utilization of the technology towards the desired objectives.

Chungu et al (2001) used the integrated model to assess the appropriateness of the village level IPI sugar processing technology in the four regions of Tanzania, namely, Arusha, Kilimanjaro, Morogoro and Ruvuma. The business model could not explain the social, technical, economic and cultural aspects, and thus, determine the performance of the technology at the said village.

CONCLUSION

Most of technology assessment methods and technology choice models have been found not suitable for assessing and choosing technologies for rural development. A review of the existing nine technology assessment methods show that none of those methods individually meet the requirement for assessing technologies for the desired socio-economic development for a specified context. A pre-requisite of an assessment method for rural development, among other factors, should be simple to be used by extension workers or local experts; saves time and resources; take into account all factors affecting technology adoption such as technical, economic, socio-cultural, political and environmental aspects; and also allow the participation of the user of the technology in the assessment process.

Three technology assessment methods have been identified on their merits and incorporated into the model, which has been developed in order to enrich the assessment process. The cost-benefit analysis has been found best in the ability in time and resource saving, whereby the analytical hierarchy method is best suited for prioritisation, and the Delphi technique is best for weighting of the evaluation criteria. These positive features have been adopted and incorporated in the integrated model which operates on the concept of fitness of technology thus integrating them all into one model that assesses the technology based on the needs and requirements of the user.

The integrated model has been developed theoretically based on empirical technology assessment methods and technology choice model evidences. The developed integrated model apart from selecting a technology from a shelf of alternatives, it also helps to identify key areas where the receiving person or organization can make improvements either on the technology or his/her attributes for effective use of the technology.

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APPENDIX A: AHP PROCEDURE

ANALYTICAL HIERARCHY PROCESS (AHP) PROCEDURE

A major portion of the analytical hierarchy process (AHP) discussion is taken from SAATY (1980), pages 17 to 21. The analytical hierarchy process method as pointed out by SAATY (1980) can be described as follows: "Given the elements of one level, say, the fourth, of a hierarchy and one element, e, of the next higher level, compare the element of level 4 pairwise in their strength of influence one. Insert the agreed upon numbers, reflecting the comparison in a matrix and find the eigenvector with the largest eigenvalue. The eigenvector provides the priority ordering, and the eigenvalue is a measure of the consistency of the judgment".

Let us determine a priority scale in the following example. Let A,B,C,D stand for chairs, arranged in a straight line, leading away from a light. Develop a priority scale of relative brightness for the chairs. "Judgments will be obtained from an individual who stands by the light source and is asked, for example, *How strongly brighter is chair B than chair C?*" The interviewee will then give one of the numbers for comparison described below and this judgment will be entered in the matrix in position (B, C). "By convention, the comparison of strength is always of an activity appearing in the column on the left against an activity appearing in the row on top. We then have the pair wise comparison matrix with four rows and four columns (a 4 x 4 matrix)". "Given elements A and B: if

A and B are equally important, insert 1

A is weakly more important than B, insert 3

A is strongly more important than B, insert 5

A is demonstrably or very strongly more important than B, insert 7

A is absolutely more important than B, insert 9

in the position (A,B) where the row of A meets the column of B. An element is equally important when compared with itself, so where the row of A and column of A meet in position (A, A) insert 1". Thus the main diagonal of a matrix must consist of 1's as shown in Table A.1. "Insert the appropriate reciprocals 1, 1/3, ..., or 1/9 where the column of A meets the row of B, i.e., position (B,A) for the reverse comparison of B with A. The numbers 2,4,6,8 and their reciprocals are used to facilitate compromise between slightly differing judgments".

"There are sixteen spaces in the matrix for our numbers. Of these, four are predetermined, namely, those in the diagonal, (A,A), (B,B), (C,C), (D,D), and have the value 1, since, for example, chair A has the same brightness as itself. Of the remaining twelve numbers, after the diagonal is filled in, we need to provide six, because the other six are reverse comparisons and must be reciprocals of the first six. Suppose the individual, using the recommended scale, enters the number 4 in the (B,C) position. He thinks chair B is between weakly and strongly brighter than chair C. Then the reciprocal value ¼ is automatically entered in the (C,B) position". After the remaining five judgments have been provided and their reciprocals also entered, we obtain for the complete matrix" in Table A.1.:

"The next step consists of the computation of a vector of priorities from the given matrix. In mathematical terms the principal eigenvector is computed, and when normalized becomes the vector priorities". In the absence of a computer to solve the problem exactly, Saaty has recommended a very good approximation of that vector by multiplying the n elements in each row and taking the nth root. Then, the resulting numbers are normalized. In the chair brightness example, $n=4$. Also in assessing the relative importance of the four components of technology, n is equal to 4. Applying the method for the chair brightness example, multiply the elements in each row of Table A.1 to get a column (210, 4.8, 0.167, 0.006) and take the 4th root which provides (3.81, 1.48, 0.64, 0.28).

Table A.1: Entries of analytical hierarchy process for a 4x4 matrix of chair's brightness

Brightness	A	B	C	D
A	1	5	6	7
B	1/5	1	4	6
C	1/6	1/4	1	4
D	1/7	1/6	1/4	1

Source: SAATY (1980)

Normalize the resulting numbers (3.81, 1.48, 0.64,0.28) (add and divide each number by this sum) obtaining column vector of priorities as 0.61, 0.24, 0.10, 0.4 for A,B,C,D respectively.

A crude estimate of consistency as pointed out by Saaty is obtained by multiplying the "matrix of comparison (Table A.1) on the right by the estimated solution vector obtaining a new vector. If we divide the first component of this vector by the first component of the estimated solution vector, the second component of the new vector by the second component of the estimated solution vector and so on, we obtain another vector. If we take the same of the components of this vector and divide by the number of components we have an approximation to a number l_{max} (called the maximum or principal eigenvalue) to use in estimating the consistency as reflected in the proportionality of preferences. The closer l_{max} is to n (the number of activities in the matrix) the more consistent is the result". Deviation from consistency may be represented by $(l_{max} - n)/(n-1)$ which Saaty called the consistency index (CI). He also called the consistency index of a randomly generated reciprocal matrix from scale 1 to 9, with reciprocals forced, the random index (RI). The average RI are shown in Table A.2 with respect

Table A.2 The order of the matrix (*n*) and its corresponding average RI

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source: SAATY (1980)

to the order of the matrix (*n*). the ratio of CI to the average RI for the same order matrix is called the consistency ratio (CR). A consistency ratio of 0.10 or less is considered acceptable.

To illustrate the approximate calculation of CI, we use the matrix Table A.1 to find l_{max}. We had (0.61, 0.24, 0.10, 0.04) or the vector of priorities. If we multiply the matrix (Table A.1) on the right by this vector we get the column vector (2,69, 1.00, 0.42, 0.19). If we divide corresponding components of the second vector (2,69, 1.00, 0.42, 0.19) by first (0.61, 0.24, 0.10, 0.04) we get (4.41, 4.17, 4.20, 4.75) Summing over these components and taking the average gives 4.38.

This gives (4.38 – 4)/3=0.13 for the CI. To determine how good this result is we divide it by the corresponding value RI=0.90 from Table A.2. The consistency ratio (CR) is 0.13/0.90=0.14, which is perhaps not as close as we would like to 0.10. Therefore, revise the importance rating by conducting another interview at a more convenient time for the interviewee. More elaborate discussion regarding analytical hierarchy process could be found in SAAT (1980).