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The Influence of Development Perspectives on the Choice of Technology

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ABSTRACT

Studies on choice of technology are aimed at discovering the development-promoting potential of a specific technology. This requires a holistic description of alternative technologies through a unified set of attributes; followed by a ranking of alternatives within a given development perspective.

In this paper the problem of choice of technology is viewed as a technology-ranking problem and is studied by relating it to two development perspectives labeled as: 1) regional self-reliant development and 2) market or growth-oriented development.

Five technology alternatives in toilet soap-making are ranked by the application of Analytic Hierarchy Process (AHP). It is shown that the rankings are significantly altered when the development perspective is changed.

Introduction

When the process of "development" is to be steered through a planning mechanism, it becomes necessary to consciously link "technology" to "development." It has long been recognized that "technology" in such circumstances, must be viewed "not only as objects and material processes, but also as organized forms, methods of production and decision-making" [1].

The concept of "development" is necessarily normative and is meant to respond to the social, economic, cultural, and political constraints of a given society. The concept defines societal goals and facilitates prescription of practical policy options. The purpose of technology then is to promote realization of these options, so that societal goals are achieved.

There is considerable truth in the proposition that many developing countries have sought to closely link the industrial policies, rather than the technology policies, to the

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socioeconomic problems. Thus in India, for example, the policy of import-substitution industrialization was intended to promote self-reliance, or the policy of small-scale industrial production was intended to bring about balanced regional development and reduce the unemployment problem. Any notions of a technology policy were thus to be operationalized sectorally, rather than through a special organizational or institutional frame.

It is this indirect relationship between technology and socioeconomic policies, we believe, that is at the root of much of the debate about appropriate technologies. Thus, it is not uncommon to find that appropriate technologies cannot be promoted in developing countries on a large scale in the presence of organizational and institutional barriers [2, 3, 4]. Finally, as globalization strategies gain prominence, there is a fear that the indirect relationship between technology and socioeconomic policies may be turned into a divorce!

It is concerns such as these that have led us to make a demonstration in this paper that the choice of technology is strongly dependent on the development perspective of the decision makers. When the question of choice of technology is considered to have such wide implications, three issues assume importance:

1. It should be possible to describe technology alternatives through a unified and holistic set of criteria (which are both quantitative and qualitative) so that impacts of alternatives in several directions can be assessed.
2. The choice of technology problem should be viewed as a technology-ranking problem, where the rankings are arrived at through multi-criteria analysis that is capable of handling both quantitative and qualitative criteria.
3. It should be possible to articulate the main preferences or compulsions of different development perspectives through their "attitude" toward the quantitative and qualitative criteria that are used to characterize the technology alternatives.

In this paper, we take the example of soap-making technology and characterize the five alternatives of this technology through 16 attributes (see Section 3). For ranking of alternatives, we use the Analytic Hierarchy Process (AHP) methodology in preference to the cost-benefit analysis and other multi-criteria methods for reasons mentioned in Section 2. The mechanism of AHP methodology is described in Section 4. Finally we subject technology rankings to the compulsions and preferences of two development perspectives labeled loosely as: (1) "Regional self-reliant" development, (2) "Market or growth-oriented" development. To do this we characterize the main attitudes of the two perspectives as they relate to the attributes used for describing the technology alternatives. We believe that establishment of this direct relationship between technology and development perspectives is essential for assessing the development-promoting potential of the technology alternatives. The characteristics of the two development perspectives are shown in tabular form in Section 5. This characterization is derived from the literature on development as well as from the objectives stated in several governmental, private and nongovernmental organizations that are known to us. Nonetheless, it is not uncommon to come across decision makers, who candidly express that "my personal preference leans toward perspective 1, but my organization supports perspective 2" and vice versa [2].

The AHP methodology requires pairwise comparison of attributes to arrive at the attribute weights and pairwise comparison of alternatives with respect to each one of the qualitative attributes to arrive at the quantitative values for the qualitative attributes. Ideally, it would be necessary therefore to carry out a Delphi exercise with decision makers with different development perspectives. With limited resources at our command, however, we have "made-up" the pairwise comparisons by imagining ourselves to be promoters of a specific development perspective. In this respect, we have of course been guided by our experience of decision makers during the period of data-collection on soap-making alternatives. It is possible that we may have over- or under-reacted in respect of a particular criterion compared to how an active decision-maker might have. In order to partially compensate for this lacuna, we have carried out sensitivity analysis of the rankings derived with respect to the development perspectives. The results of this analysis are described in Section 7.

In view of this, the rankings indicated under two perspectives in Section 5 may be considered to be only indicative, rather than as conclusive as could be assessed by using the data from active decision makers. But then, the primary objective of this paper is to demonstrate that the rankings indeed do change, and often drastically, under different development perspectives.

In a way, the above-mentioned change in rankings can be logically expected in any technology as has been our experience [5] from studies of six more technologies. At any rate, on the basis of findings from these studies, it appears appropriate to make a plea that multi-criteria analysis should be subjected to the imperatives of different development perspectives.

Literature Review

Whenever a technology is to be evaluated, we need to take into account all the available alternatives with their characteristics in terms of capital requirement, employment potential, infrastructure requirement, environmental effects, etc. There are not many studies on the characterization of technology alternatives based on techno-socio-economic factors relevant for judging their appropriateness. Date [2] has done characterization of technology alternatives in four technologies: namely soap-making, vegetable oil extraction, leather tanning, and water purification. Baron [6] has presented case studies on the choice of technologies in 11 food-processing industries with reference to their appropriateness for third world countries. Karmarkar [7, 8, 9] has characterized the alternatives in cement making, brick making, and rice milling.

Usually the choice of technology from a list of alternatives is identified on the basis of either technical efficiency or economic efficiency. Problems associated with decision making based on either technical efficiency or economic efficiency are discussed by Sen [3]. Cost-benefit analysis, which is traditionally used whenever big projects are undertaken by governments and public sector undertakings, can also be used to evaluate alternatives. Two important criticisms against this approach are: (1) it ignores distributive equity (who benefits at whose costs), (2) it is very difficult to translate all risks, costs, and benefits in monetary units. Expressing all risks, costs, and benefits in monetary terms brings in all the problems of market distribution. A very good discussion on historical, methodological, and ethical issues of technology assessment by cost-benefit analysis can be found in [10].

In the literature of multi-criteria analysis, there exists a number of methods for analyzing the choice of technology problems. Simple weighted average method [11], Elimination and Choice Translation Algorithm (ELECTRE) [12], Preference Organization Method for Enrichment Evaluation (PROMETHEE) [13] and Analytic Hierarchy Process (AHP) [14] are some of the common methods found suitable for evaluation of technology alternatives. In the simple weighted average method, ELECTRE and PROMETHEE there is no formal procedure for evaluation of weights. The AHP provides a pairwise comparison method for arriving at weights and also a measure for consistency of pairwise comparisons. The AHP also helps in quantifying the qualitative attributes.

TABLE 1
Technology Alternatives in Toilet Soap-making

Alternative	Process description	Scale
T1	Semi-cum full-boiled process using nonedible oil without glycerin recovery	Cottage
T2	Cold process using edible oil and mutton tallow without glycerin recovery	Small
T3	Full-boiled process using fatty acids and wastes from edible oil refining with glycerin recovery	Medium
T4	High-pressure splitting of nonedible oil and mutton tallow with glycerin recovery	Large
T5	Fatty acid production using Twitchell's process followed by saponification with glycerin recovery	Medium

From Ref. [2].

Another important advantage of the AHP is in structuring a decision problem into a number of hierarchical levels. Because of these advantages the AHP is chosen for analyzing the technology alternatives in this paper.

The Analytic Hierarchy Process is applied in a large number of applications in multi-criteria decision making in planning, priority setting, resource allocation, and conflict resolution. Lusk [15] applied the AHP for decision making in capital management in a hospital set-up. Ramanujam et al. [16] proposed the use of the AHP for the assessment and selection of imported technologies for less-developed countries. The AHP approach is used by Sharif et al. [17] for selecting the mode of mass transport for Bangkok. Sharif et al. [18] have also presented two case studies for the selection of appropriate technologies for rural development in Indonesia. Zehedi [19] and Vargas [20] have provided good reviews of the applications of this method available in the literature. Recently AHP methodology was used by Prasad et al. [21] for the choice of technology alternatives in Indian telecommunications.

In most of the cases found in literature, the problems for ranking are not comprehensively described in terms of their relevant attributes. This is specially true in the case of ranking of technology alternatives. In the case of choice of technology for national and rural development analyzed in [16] and [18], technologies are assumed to be neutral to the development perspective of the decision maker. The choice of technology studies found in the literature on multi-criteria analysis are generally done in isolation from the specific political, social, and institutional context. Sen [3] stresses the importance of institutional, economic, and political feasibility considerations connected with appropriate technological choices for development. Sen argues that even if appropriate technological alternatives are known to exist and are economically efficient, they are unlikely to be easily disseminated and applied unless adequate criteria, policies, and institutions for decision making are introduced in favor of the development objectives (such as creation of greater employment potential, sustainable rates of resource use). In this paper, we deal with the interrelatedness of technology choice and development perspective with an example on ranking of the technology alternatives in soap making.

Technology Alternatives in Soap-Making

There are five technology alternatives in toilet soap-making in India as studied by Date [2]. The process details of these alternatives are shown in Table 1 and their detailed characteristics are given in Tables 2(a) and 2(b). It can be seen from these tables that the alternatives T1, T2, T3, T4, and T5 differ in the process, size, capital requirement, employment potential and the other resources required. The alternative T1 is a cottage

TABLE 2(a)
Characteristics of Technology Alternatives in Toilet Soap-making (Quantitative Attributes).

Attribute	T1	T2	T3	T4	T5
A1. Capacity per day (Kg)	126.	300.	10000.	18000.	10000.
A2. Capital per tpd. capacity (Rs. lakhs)	4.762	4.167	10.	12.5	13.
A3. Workers per tpd. capacity	71.429	333.333	15.6	3.889	19.4
A4. Time to set up (months)	2.	2.	12.	24.	12.
A5. Energy (thermal) per ton. output (KWH)	16000.	0.	4100.	2740.	5100.
A6. Energy (mech.) per ton. output (KWH)	0.	0.	450.	360.	550.
A7. Water per Kg. output (lts.)	19.	15.	10.	66.	17.
A8. Glycerin recovery per ton. soap (Kg)	0.	0.	40.	90.	80.

From Ref. [2]

level unit and can be set up even in remote rural areas. It is based on a semi-cum-full boiled process and it is being promoted by Khadi and Village Industries Commission in India. The second one, T2, is a small scale unit existing in small industrial estates in urban areas. This uses cold process. The third alternative, T3, is a medium-scale operation existing as part of bigger enterprises dealing in oils and fats. The fourth one is a very large-scale plant producing toilet soap from fatty acids. The fifth alternative is a medium-scale unit with fatty acids production using Twitchell's process. The data presented in these tables were collected from interviews with owners, corporate managers and consulting engineers, from industry-association journals and government reports.

TABLE 2(b)
Characteristics of Technology Alternatives in Soap-making (Qualitative Attributes)

Attribute	T1	T2	T3	T4	T5
A9. Raw material	neem oil, palm oil, coconut oil, rosin and silicates	coconut oil, mutton tallow, palm oil, rosin and silicates	fatty acids + by products of groundnut oil refining, rosin and silicates	fatty acids, rosin and silicates	fatty acids, rosin and silicates
A10. Energy source	firewood	firewood, kerosene	electricity, furnace oil	electricity, furnace oil	electricity, furnace oil
A11. Location	village	big village, taluka place	city	city	town
A12. Skills	learning by doing	learning by doing	science based	science based	science based
A13. Degree of mechanization	hand operated	hand operated	completely mechanized except packaging	completely mechanized	partially mechanized
A14. Design and fabrication	indigenous	indigenous	imported but can be made in India	imported as indigenous machinery not reliable	indigenous
A15. Transport	truck, bullock cart	truck, bullock cart	truck	truck-cum-rail	truck
A16. Waste disposal	spent lye in very small quantities and loss of glycerin	nil	wash water with bearing oils and chemicals	complete water treatment plant required	wash water with bearing oils and chemicals

From Ref. [2].

The alternatives in soap-making are characterized by 16 attributes A1, A2, . . ., A16. Table 2(a) shows the quantitative attributes, whereas Table 2(b) shows the qualitative ones. In the case of quantitative attributes, the dimensions and ranges of the values are different. In addition to this, the quantitative attributes can be grouped into two types: (1) benefit attributes, (2) cost attributes. In the case of benefit attributes, the higher the numerical value of the attribute, the more preferable the alternative is with respect to that attribute. In the case of the cost attribute, the lower the numerical value of the attribute, the more preferable the alternative is with respect to that attribute. This classification is borrowed from [12]. Whether a particular quantitative attribute is a benefit type or cost type depends on the development perspective of the decision maker. For example, a decision maker interested in maximizing the employment potential would consider the attribute A3 (workers per unit capacity) in Table 2(a) as a benefit attribute. The same attribute would be considered as a cost attribute by the decision maker interested in minimizing the employment requirement.

Generally, decision making in choice of technology takes place based on only a few criteria and most of the time it is based mainly on economic criteria. In addition to this, the decision making process does not consider the spectrum of alternatives existing. The information presented on various technology alternatives with respect to a number of relevant attributes as in Tables 2(a) and 2(b) improves the decision making in appropriate choice of technologies. Even a qualitative study of these tables provides some clues to arrive at a suitable alternative for a particular region. In the next sections, we use the Analytic Hierarchy Process methodology for evaluating the technology alternatives in soap-making.

Ranking of Technology Alternatives in Soap-Making

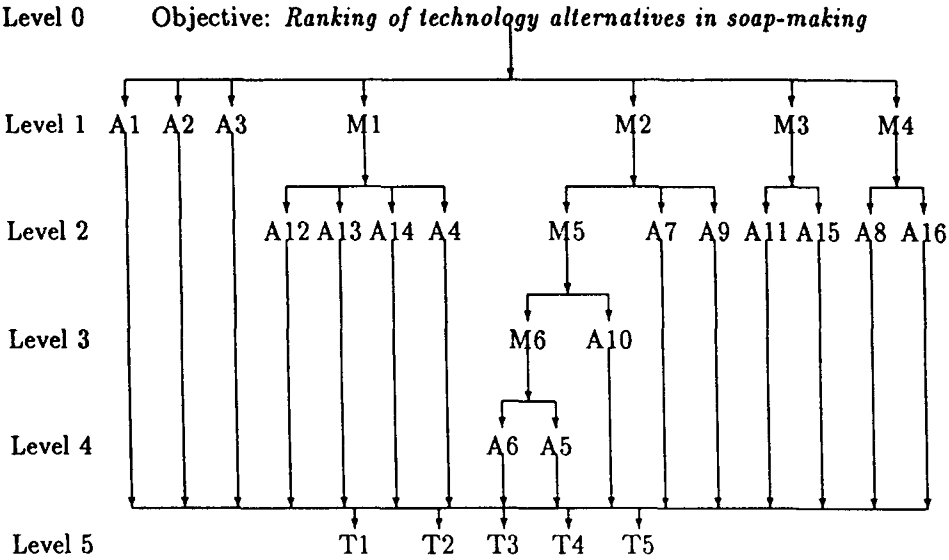
If we know the normalized attribute values p_{ij} of the alternatives and the attribute weights w_i, then the ranking of our alternatives can be arrived at by finding out R_j by Equation 1.

$$R_j = \sum_{i=1}^{16} p_{ij} w_i \qquad (1)$$

Here p_{ij} is the normalized attribute value of the jth technology alternative with respect to the ith attribute. The weight of the ith attribute is denoted by w_i. R_j provides the basis for ranking of the technology alternatives. Higher the value of R_j, the better is the jth alternative.

Hence for the ranking of the alternatives, we need to normalize the quantitative attribute values, arrive at the quantitative values for the qualitative attributes and the weights for all the attributes.

The Analytic Hierarchy Process provides a good framework for hierarchically decomposing the problem into a number of levels, which helps in arriving at attribute weights by pairwise comparisons. Using the AHP approach, the problem of technology alternatives in soap-making is hierarchically decomposed into 5 levels as shown in Figure 1. We have arranged all the 16 attributes into a number of groups in different levels by introducing new attributes (M1 to M6) in such a way that all the attributes characterize the soap-making alternatives hierarchically. Such hierarchical decomposition is done to facilitate the process of arriving at the weights for the attributes. In this hierarchical structure, the technology alternatives in soap-making are considered to be characterized by 7 main attributes in Level 1: *Capacity per day* (A1), *Capital per unit capacity* (A2),



Level 1 attributes:

A1 : Capacity per day

A2 : Capital per unit capacity

A3 : Workers per unit capacity

M1 : Hardware characteristics

M2 : Resources requirement

M3 : Infrastructure requirement

M4 : Environmental effects

Level 2 attributes:

A12: Skills

A13: Degree of mechanization

A14: Design and fabrication

A4 : Time to set-up
M5 : Energy

A7 : Water
A9 : Raw material

A11: Location
A15: Transport

A8 : Glycerin recovery
A16: Waste disposal

Level 3 attributes:

M6 : Energy intensity

A10: Nature of energy source

Level 4 attributes:

A6 : Mechanical energy
A5 : Thermal energy

Level 5 alternatives:

T1, T2, T3, T4 and T5 are the technology alternatives in soap-making

Fig. 1. Hierarchical decomposition of the attributes in soap-making.

Workers per unit capacity (A3), *Hardware characteristics* (M1), *Resources requirements* (M2), *Infrastructure requirements* (M3), and *Environmental effects* (M4). M1, M2, M3, M4 are new attributes under which A4, A5, . . ., A16 are grouped hierarchically.

The attributes M1, M2, M3 and M4 in Level 1 are characterized by the attributes at Level 2. *Hardware characteristics* (M1) is characterized by *Skills requirement* (A12), *Degree of mechanization* (A13), *Design and fabrication difficulties* (A14) and *Time required to set up the plant* (A4). The attribute *Resources requirements* (M2) is characterized by *Energy requirement* (M5), *Water requirement* (A7) and *Raw material requirement* (A9). The attribute *Infrastructure requirement* (M3) is characterized by *Location constraints* (A11) and *Transport requirement* (A15). Finally the *Environmental effects* (M4) is characterized by *Glycerin recovery* (A8) and *Waste disposal* (A16).

The attribute *Energy requirement* (M5) at Level 2 is further characterized by *Energy intensity* (M6) and *Nature of energy source* (A10) at Level 3. *Energy intensity* (M6) at Level 3 is characterized by *Mechanical energy* (A6) and *Thermal Energy* (A5) at Level 4. The Level 5 contains 5 technology alternatives in soap-making: T1, T2, T3, T4 and T5. The 16 attributes connected to Level 5: A1, A2, . . ., A16 characterize the technology alternatives T1. . . T5. The quantitative values or qualitative description of the five technology alternatives with respect to the 16 attributes can be taken from Tables 2(a) and 2(b).

For arriving at the weights for attributes at any level, we do the pairwise comparison of the attributes based on the scale of relative importance (ranging from 1 for equal importance to 9 for extreme importance) given by Saaty [14]. Pairwise comparison of the attributes at any level is done with respect to their relative importance to the attribute to which they are connected at the next higher level. Eigen vector corresponding to the maximum eigen value (λ_{max}) of the pairwise comparison matrix is normalized to sum to 1 to arrive at the priority vector for the attributes. This priority vector is taken as the attribute weights vector. Pairwise comparison matrix is assumed to be consistent if consistency index, $CI = (\lambda_{max} - n)/(n - 1) \leqslant 0.1$ where n is the number of attributes compared. If $CI > 0.1$, pairwise comparison is repeated.

Let $[a_1\ a_2\ a_3\ m_1\ m_2\ m_3\ m_4]$ represent the priority vector of the pairwise comparison matrix of the main attributes A1, A2, A3, M1, M2, M3, and M4. In Level 2, the attributes A12, A13, A14, and A4 are pairwise compared with respect to their relative importance to M1 and their priority vector $[a_{12}\ a_{13}\ a_{14}\ a_4]$ is obtained. Similarly priority vectors $[m_5\ a_7\ a_9]$, $[a_{11}\ a_{15}]$ and $[a_8\ a_{16}]$ are obtained. In Levels 3 and 4 we obtain priority vectors $[m_6\ a_{10}]$ and $[a_6\ a_5]$. Now the overall weights vector, $[w_1\ w_2 \ldots w_{16}]$ for the attributes is arrived at by successively multiplying the attribute weights from Level 1 to Level 4. For example, w_1, w_2, and w_3 are equal to a_1, a_2 and a_3, respectively; w_{12} is equal to a_{12} multiplied by m_1. Similarly w_6 is equal to $a_6 m_6 m_5 m_2$.

Using the pairwise comparison method of AHP, we can also arrive at quantitative values for qualitative attributes A9 to A16. Technology alternatives T1, T2, T3, T4, and T5 are pairwise compared with respect to each of these attributes and the priority vectors are evaluated. The qualitative description given in Table 2(b) for the alternatives with respect to the attributes A9 to A16 can be taken as guideline for pairwise comparison. The priority vectors obtained in this way for qualitative attributes can be considered as their normalized attribute values.

The normalized attribute values for the quantitative attributes A1 to A8 can be arrived at by the following normalization scheme:

for benefit attributes:

$$p_{ij} = \frac{t_{ij} - t_i^{min}}{t_i^{max} - t_i^{min}} \tag{2}$$

for cost attributes:

$$p_{ij} = \frac{t_i^{max} - t_{ij}}{t_i^{max} - t_i^{min}} \tag{3}$$

where t_{ij} is the attribute value of the jth alternative with respect to the ith attribute and t_i^{max} and t_i^{min} are the absolute maximum and minimum values among all the alternatives for the ith attribute (i = 1 to 8, j = 1 to 5).

Now the priority vectors of all the 16 attributes (quantitative + qualitative) connected to the Level 5 are combined together to form [P], which we call as the normalized attributes matrix. The ranking of the alternatives is evaluated using Equation 1. Higher the value of R_j, the better is the jth alternative. In the next section, we introduce development perspectives and rank the alternatives in soap-making with respect to two developmental perspectives.

Development Perspectives and Ranking of the Alternatives

Because development is a normative concept, the choice of technology becomes perspective-specific; as such decision makers with different development perspectives view the development in different ways and they have different priorities. Some people view the development aiming at satisfaction of the basic needs of all the people. Everyone may not view the development in the same light. Even to achieve the satisfaction of the basic needs of all the people, varied perspectives are held by people. In some perspectives employment creation, minimization of pollution, and sustainable resource use are more important, whereas in some perspectives minimization of employment requirement and maximization of economic efficiency are more important.

We can identify some dominant features of development and put them under "regional self-reliant development" (perspective 1) and "market or growth-oriented development" (perspective 2). We have tried to describe these two perspectives against the same set of attributes that we have used for describing the technology alternatives. The description of the development perspectives with respect to the quantitative and qualitative attributes are shown in Tables 3(a) and 3(b), respectively. This characterization is developed considering how the decision makers with the two perspectives view the soap-making technologies with respect to the 16 attributes. In reality one may not find decision makers having either only perspective 1 or perspective 2 but varying shades of these two. Here we have considered only "regional self-reliant" and "growth oriented" perspectives to highlight the dependence of the ranking of the alternatives on the development perspectives.

The weights given to the attributes and the quantitative values given to the qualitative attributes represent the development perspective of the decision maker. In the AHP method for the ranking of the technology alternatives, decision makers with different development perspectives will give different ratios in pairwise comparison matrices. This leads to different attribute weights or priority vectors. In the case of the quantitative attributes, the nature of the attributes (benefit or cost attribute) may differ in different perspectives. Hence normalized priority vectors for the quantitative attributes depend on the perspectives. The nature of the quantitative attributes (cost or benefit) assumed with respect to the two development perspectives is shown in Table 4. The nature of all the attributes is the same except that of Workers per unit capacity (A3). We assumed here that the "regional self-reliant development" (perspective 1) aims at maximizing the employment potential. Hence the attribute A3 is assumed to be a benefit attribute. But in the "market or growth-oriented development" (perspective 2), it is assumed that the decision maker aims at minimizing the employment requirement and hence the attribute A3 is taken as a cost attribute.

Pairwise comparison matrices of the attributes in Levels 1 to 4 with respect to the two development perspectives are shown in Tables 5 and 6. λ_{max}, CI and the priority

TABLE 3(a)
Characteristics of the Two Developmental Perspectives (with Respect to Quantitative Attributes

Attribute	Regional self-reliant development (Perspective 1)	Market or growth-oriented development (Perspective 2)
A1. Capacity	preference to smaller capacity units so that decentralized units can be established to serve the local needs	preference to larger capacity units to serve bigger markets
A2. Capital per unit capacity	low capital units so that capital can be raised in the region itself	capital constraint is not so much, it can be generated from diverse sources
A3. Workers per unit capacity	maximizes employment potential	minimizes employment requirement
A4. Time to set up	there is a natural advantage for the faster completion of the projects because they depend on local resources and local labor	investors cannot tolerate the delays and delays occur because of their dependence on outside resources
A5,A6. Energy requirement	energy efficiency may be very low, but mostly renewable energy resources are used	energy intensive in using non-renewable resources
A7. Water requirement	less water intensive projects are preferred as water needs for other areas (drinking, agriculture) are kept in mind	unless heavy charges or controls are levied, there is minimal concern for reducing water consumption
A8. Glycerin recovery	there is not much concern for recovery of byproducts, technology for this is also costly	profit motive encourages extensive processing for byproducts, sometimes primary product loses the quality (e.g., rice milling with bran recovery)

vectors are also shown there. Pairwise comparisons of the alternatives with respect to each qualitative attribute are shown in Table 7. For all these pairwise comparisons, the information given in Table 2(b) and the contrasting assumptions behind the development perspectives shown in Tables 3(a) and 3(b) are taken as references. The normalized attribute values for quantitative attributes (based on Equations 2 and 3) and priority vectors for qualitative attributes (from Table 7) are combined together to arrive at a normalized attributes matrix $[P]_{16X5}$ for the two development perspectives and they are shown in Table 8. The overall attribute weights $[w_1\ w_2\ \ldots\ w_{16}]$ are also shown in Table 8. Now the ranking of the alternatives is achieved by Equation 1 and the summary of the rankings is shown in Table 9, which clearly indicates how drastically the rankings differ in the two development perspectives.

Discussion of Results

The ranking results in Table 9 show the importance of taking into consideration the development perspectives of the decision makers while looking at their choice of technology decisions. This is possible by characterizing the development perspectives with respect to the same set of attributes that characterize the given technology alternatives.

In the hierarchical decomposition of attributes in Figure 1, capacity, capital, employment, hardware, resources, infrastructure, and environmental effects are the most important attributes. As arrived by pairwise comparison of these attributes in Table 5, the "regional self-reliant" development (perspective 1) has employment as the most important

TABLE 3(b)
Characteristics of the Two Developmental Perspectives (with Respect to Qualitative Attributes)

Attribute	Regional self-reliant development (Perspective 1)	Market or growth-oriented development (Perspective 2)
A9. Raw material	projects are chosen for using mainly the local raw material	projects are chosen for varying market situations. projects using diverse raw materials are preferred
A10. Nature of energy source	prefers use of locally-available renewable resources	preference for conventional forms of energy resources
A11. Location	village and taluka level location is preferred for decentralized production	urban oriented location is preferred to be close to the bigger markets and modern infrastructure
A12. Skills	prefers to use and enhance local skills	universal skills based on S and T inputs are preferred
A13. Degree of mechanization	mechanization to minimize labor is avoided as far as possible, mechanization is meant for only reducing the drudgery, that is, interest in manufacture	complete mechanization is the goal, that is, interest in machinofacture
A14. Design and fabrication	indigenously designed projects are preferred to encourage local talents and for more reliability	dependence on indigenous design comes only when borrowing is difficult, liberalization and import of advanced technology are the dreams
A15. Transport	objective is to reduce the distance between production and consumption, heavier transport requirements are avoided	raw material from far off places and products to again far off places have to be transported, heavier and faster transportation is required
A16. Waste disposal	minimization of wastes to reduce pollution of local resource-base	least concern for the local environment leads to production of wastes at the source, only controls and concessions lead to pollution control

TABLE 4
Nature of the Quantitative Attributes in the Two Developmental Perspectives

Attribute	Nature of the attribute	
	perspective 1	perspective 2
A1. Capacity	benefit	benefit
A2. Capital per unit capacity	cost	cost
A3. Workers per unit capacity	benefit	cost
A4. Time to set-up	cost	cost
A5. Thermal energy	cost	cost
A6. Mechanical energy	cost	cost
A7. Water	cost	cost
A8. Glycerin recovery	benefit	benefit

TABLE 5
Pairwise Comparison of Attributes at Level 2 for Perspectives 1 and 2

	A1	A2	A3	M1	M2	M3	M4	Priority vector
A1	1	1/2	1/7	3	1/5	2	2	0.084
A2	2	1	1/2	6	2	5	4	0.221
A3	7	2	1	8	3	7	4	0.377
M1	1/3	1/6	1/8	1	1/4	1/2	1/3	0.032
M2	5	1/2	1/3	4	1	3	2	0.168
M3	1/2	1/5	1/7	2	1/3	1	1/2	0.046
M4	1/2	1/4	1/4	3	1/2	2	1	0.073
				$\lambda_{max} = 7.36$, $CI = 0.06$ Perspective 1				
A1	1	2	7	3	6	4	8	0.366
A2	1/2	1	6	2	5	3	7	0.252
A3	1/7	1/6	1	1/4	1/2	1/3	2	0.042
M1	1/3	1/2	4	1	3	2	5	0.154
M2	1/6	1/5	2	1/3	1	1/2	2	0.058
M3	1/4	1/3	3	1/2	2	1	3	0.096
M4	1/8	1/7	1/2	1/5	1/2	1/3	1	0.032
				$\lambda_{max} = 7.13$, $CI = 0.02$ Perspective 2				

attribute followed by capital, resources, capacity, environment, infrastructure, and hardware. The "growth-oriented" development (perspective 2) has the capacity as the most important attribute followed by capital, hardware, infrastructure, resources, employment, and environment. Similar differences can be seen in the priorities of attributes in Level 2 to 4. This shows the drastic differences among the priorities in the two development perspectives, which get reflected in the ranking of alternatives. The characteristics of technology alternatives in Table 2(a) and 2(b) and the attribute matrices in Table 8 also indicate that alternatives T1 and T2 rank high in perspective 1 and alternatives T3 and T4 rank high in perspective 2. This is more clearly reflected in Table 9.

Sensitivity Analysis

Sensitivity analysis is carried out to study how the rankings change with removal of different attributes. This is to see how rankings change if a particular attribute does not play any significant role in technology selection. We have considered only the main attributes A1, A2, A3, M1, M2, M3, and M4 for the sensitivity analysis. When an attribute is removed, a new priority vector for the other attributes are obtained by deleting that attribute from the original pairwise comparison matrix and calculating the new priority vector for the remaining attributes. The ranking values, R_j for the seven cases are summarized graphically for the perspectives 1 and 2 in Figures 2 and 3, respectively. Case 0 corresponds to the original results, that is, considering all the attributes. The results of Case 1, Case 2, . . ., Case 7 are obtained by deleting the major attribute A1, A2, A3, M1, M2, M3, and M4, respectively each time. In the perspective 1, although the lower-order rankings are sensitive to the removal of a major attribute, the highest ranking is found to be independent of the removal of a major attribute. In perspective 2 also, the highest ranking is found to be independent of the removal of a major attribute except in the Case 1, that is, when the attribute A1: *Capacity per day* is removed. The ranking in perspective 2 is sensitive to the attribute A1.

TABLE 6

Pairwise Comparison of Attributes at Levels 2, 3, and 4

Regional self-reliant development perspecive (Perspective 1)						Market or growth oriented development perspective (Perspective 2)					
	Pairwise comparison matrix				Priority vector		Pairwise comparison matrix				Priority vector
	A12	A13	A14	A4			A12	A13	A14	A4	
A12	1	6	3	7	0.602	A12	1	1/5	1/4	1/5	0.063
A13	1/6	1	1/2	2	0.115	A13	5	1	1/2	1	0.263
A14	1/3	2	1	3	0.212	A14	4	2	1	1/2	0.302
A4	1/7	1/2	1/3	1	0.071	A4	5	1	2	1	0.371
	$\lambda_{max} = 4.03$, $CI = 0.01$						$\lambda_{max} = 4.19$, $CI = 0.06$				
	M5	A7	A9				M5	A7	A9		
M5	1	1	1		0.333	M5	1	5	4		0.683
A7	1	1	1		0.333	A7	1/5	1	1/2		0.117
A9	1	1	1		0.333	A9	1/4	2	1		0.200
	$\lambda_{max} = 3.00$, $CI = 0.00$						$\lambda_{max} = 3.02$, $CI = 0.01$				
	A11	A15					A11	A15			
A11	1	4			0.800	A11	1	1			0.500
A15	1/4	1			0.200	A15	1	1			0.500
	$\lambda_{max} = 2.00$, $CI = 0.001$						$\lambda_{max} = 2.00$, $CI = 0.00$				
	A8	A16					A8	A16			
A8	1	3			0.750	A8	1	2			0.667
A16	1/3	1			0.220	A16	1/2	1			0.333
	$\lambda_{max} = 2.00$, $CI = 0.00$						$\lambda_{max} = 2.00$, $CI = 0.00$				
	M6	A10					M6	A10			
M6	1	1/3			0.250	M6	1	4			0.800
A10	3	1			0.750	A10	1/4	1			0.200
	$\lambda_{max} = 2.00$, $CI = 0.00$						$\lambda_{max} = 2.00$, $CI = 0.00$				
	A6	A5					A6	A5			
A6	1	3			0.750	A6	1	3			0.750
A5	1/3	1			0.250	A5	1/3	1			0.250
	$\lambda_{max} = 2.00$, $CI = 0.00$						$\lambda_{max} = 2.00$, $CI = 0.00$				

Conclusions

- In this paper, the choice of technology problem is viewed as a technology ranking problem where the Analytic Hierarchy Process is used for the ranking of the alternatives.
- It is shown that the technology rankings are a strong function of the development perspective of the decision maker. Such a connection between the ranking of the technology alternatives and development perspectives has been made possible by characterizing the alternatives and the perspectives through the same set of generalized attributes that can be applied to any technology.
- In the soap-making example, the regional self-reliance perspective accords the highest ranking to the technology T1, whereas the growth-oriented perspective accords the highest ranking to the technology T4. In the former perspective the rank of T1 does not change when any one of the major attributes is removed. In the latter perspectives the rank of T4 is sensitive to the attribute, *Capacity per day*.
- The AHP is shown to be a very good method for ranking of technological alternatives within different development perspectives.

TABLE 7
Pairwise Comparison of Alternatives with Respect to Qualitative Attributes

	(Perspective 1)						(Perspective 2)					
Attribute	Pairwise comparison matrix					Priority vector	Pairwise comparison matrix					Priority vector
	1	7	5	6	6	0.574	1	2	1/2	1/2	1/4	0.116
A. 9 raw material	1/7	1	1/3	1/4	1/4	0.045	1/2	1	1/3	1/3	1/3	0.079
	1/5	3	1	2	2	0.162	2	3	1	1/2	1/2	0.189
	1/6	4	1/2	1	1	0.110	2	3	2	1	1	0.286
	1/6	4	1/2	1	1	0.110	4	3	2	1	1	0.331
	λ_{max} = 5.25, CI = 0.06						λ_{max} = 5.12, CI = 0.03					
A10. energy source	1	3	5	5	5	0.490	1	1/2	1/9	1/9	1/9	0.033
	1/3	1	4	4	4	0.272	2	1	1/5	1/5	1/5	0.062
	1/5	1/4	1	1	1	0.079	9	5	1	1	1	0.302
	1/5	1/4	1	1	1	0.079	9	5	1	1	1	0.302
	1/5	1/4	1	1	1	0.079	9	5	1	1	1	0.302
	λ_{max} = 5.09, CI = 0.02						λ_{max} = 5.00, CI = 0.00					
A11. location	1	3	9	9	5	0.538	1	1/2	1/7	1/7	1/7	0.045
	1/3	1	5	5	3	0.248	2	1	1/2	1/2	1/2	0.125
	1/9	1/5	1	1	1/3	0.048	7	2	1	1	1	0.277
	1/9	1/5	1	1	1/3	0.048	7	2	1	1	1	0.277
	1/5	1/3	3	3	1	0.117	7	2	1	1	1	0.277
	λ_{max} = 5.08, CI = 0.002						λ_{max} = 5.04, CI = 0.01					
A12. skills	1	1	1/3	1/3	1/3	0.091	1	1	1/2	1/2	1/2	0.125
	1	1	1/3	1/3	1/3	0.091	1	1	1/2	1/2	1/2	0.125
	3	3	1	1	1	0.273	2	2	1	1	1	0.250
	3	3	1	1	1	0.273	2	2	1	1	1	0.250
	3	3	1	1	1	0.273	2	2	1	1	1	0.250
	λ_{max} = 5.00, CI = 0.000						λ_{max} = 5.00, CI = 0.00					
A13. degree of mechanization	1	1	7	9	5	0.407	1	1	1/5	1/7	1/2	0.065
	1	1	7	9	5	0.407	1	1	1/5	1/7	1/2	0.065
	1/7	1/7	1	2	1	0.068	5	5	1	1/2	1	0.256
	1/9	1/9	1/2	1	1/2	0.041	7	7	2	1	2	0.435
	1/5	1/5	1	2	1	0.078	2	2	1	1/2	1	0.179
	λ_{max} = 5.03, CI = 0.01						λ_{max} = 5.10, CI = 0.03					
A14. design and fabrication	1	1	5	7	1	0.299	1	1	5	7	1	0.299
	1	1	5	7	1	0.299	1	1	5	7	1	0.299
	1/5	1/5	1	2	1/5	0.065	1/5	1/5	1	2	1/5	0.065
	1/7	1/7	1/2	1	1/7	0.040	1/7	1/7	1/2	1	1/7	0.040
	1	1	5	7	1	0.299	1	1	5	7	1	0.299
	λ_{max} = 5.02, CI = 0.01						λ_{max} = 5.02, CI = 0.01					
A15. transport	1	1	7	9	7	0.409	1	1	1/6	1/7	1/6	0.047
	1	1	7	9	7	0.409	1	1	1/6	1/7	1/6	0.047
	1/7	1/7	1	3	1/3	0.058	6	6	1	1/2	1	0.250
	1/9	1/9	1/3	1	1/3	0.033	7	7	2	1	2	0.408
	1/7	1/7	3	3	1	0.091	6	6	1	1/2	1	0.250
	λ_{max} = 5.27, CI = 0.07						λ_{max} = 5.05, CI = 0.01					
A16. waste disposal	1	1/2	4	8	4	0.308	1	1/2	1	7	1	0.200
	2	1	5	9	5	0.457	2	1	2	9	2	0.369
	1/4	1/5	1	5	1	0.102	1	1/2	1	7	1	0.200
	1/8	1/9	1/5	1	1/5	0.031	1/7	1/9	1/7	1	1/7	0.032
	1/4	1/5	1	5	1	0.102	1	1/2	1	7	1	0.200
	λ_{max} = 5.18, CI = 0.05						λ_{max} = 5.03, CI = 0.01					

TABLE 8
Final Attribute Weights and Normalized Attributes Matrix

	T1	T2	T3	T4	T5	
0.084	0.001	0.010	0.552	1.000	0.552	A1
0.221	0.933	1.000	0.340	0.057	0.000	A2
0.377	1.000	0.436	0.025	0.000	0.230	A3
0.002	1.000	1.000	0.545	0.000	0.545	A4
0.003	0.000	1.000	0.744	0.829	0.681	A5
0.010	1.000	1.000	0.182	0.345	0.000	A6
0.056	0.000	0.000	0.444	1.000	0.889	A7
0.055	0.161	0.089	0.000	1.000	0.125	A8
0.056	0.574	0.045	0.162	0.110	0.110	A9
0.042	0.490	0.272	0.079	0.079	0.079	A10
0.037	0.538	0.248	0.048	0.048	0.117	A11
0.019	0.091	0.091	0.273	0.273	0.273	A12
0.004	0.407	0.407	0.068	0.041	0.078	A13
0.007	0.299	0.299	0.065	0.040	0.299	A14
0.009	0.409	0.409	0.058	0.033	0.091	A15
0.018	0.308	0.457	0.102	0.031	0.102	A16
[W]			[P]			
			Perspective 1			
	T1	T2	T3	T4	T5	
0.366	0.000	0.010	0.552	1.000	0.552	A1
0.252	0.933	1.000	0.340	0.057	0.000	A2
0.042	0.000	0.564	0.975	1.000	0.770	A3
0.057	1.000	1.000	0.545	0.000	0.545	A4
0.008	0.000	1.000	0.744	0.829	0.681	A5
0.024	1.000	1.000	0.182	0.345	0.000	A6
0.007	0.000	0.000	0.444	1.000	0.889	A7
0.021	0.161	0.089	0.000	1.000	0.125	A8
0.012	0.116	0.079	0.189	0.286	0.331	A9
0.008	0.033	0.062	0.302	0.302	0.302	A10
0.048	0.045	0.125	0.277	0.277	0.277	A11
0.010	0.125	0.125	0.250	0.250	0.250	A12
0.040	0.065	0.065	0.256	0.435	0.179	A13
0.046	0.299	0.299	0.065	0.040	0.299	A14
0.048	0.047	0.047	0.250	0.408	0.250	A15
0.011	0.200	0.369	0.200	0.032	0.200	A16
[W]			[P]			
			Perspective 2			

TABLE 9
Ranking of the Alternatives in Perspectives 1 and 2

	Perspective 1		Perspective 2	
Alternative	R_j	rank	R_j	rank
T1	0.692	1	0.345	4
T2	0.448	2	0.401	3
T3	0.183	5	0.421	2
T4	0.231	3	0.526	1
T5	0.217	4	0.337	5

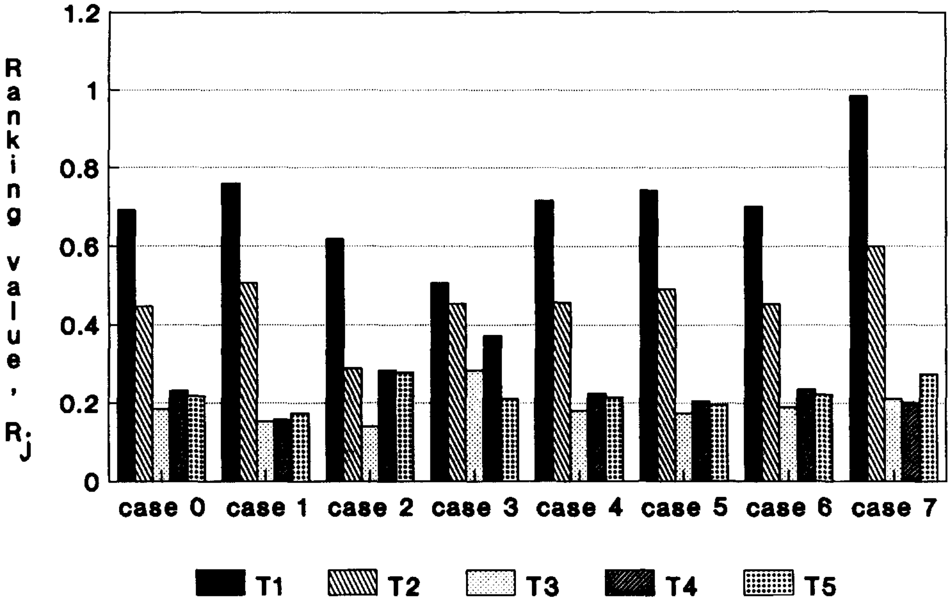


Fig. 2. Change of rankings for different cases (perspective 1).

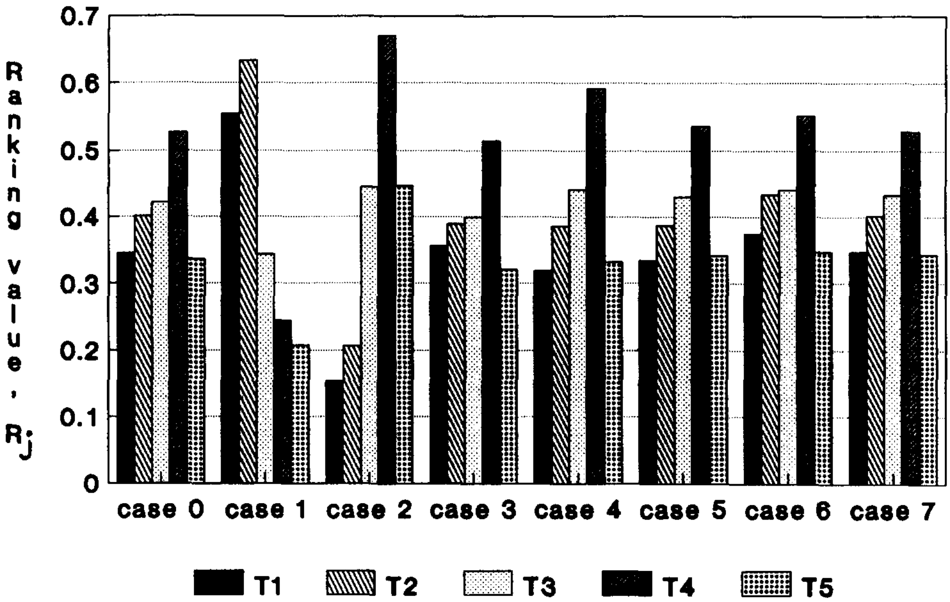


Fig. 3. Change of rankings for different cases (perspective 2).

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