DETERMINATION OF THE TECHNOLOGICAL VALUE OF COTTON FIBRE: A COMPARATIVE STUDY OF THE TRADITIONAL AND MULTIPLE-CRITERIA DECISION-MAKING APPROACHES

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Abstract

This paper presents a comparative study of the methods used to determine the technological value or overall quality of cotton fibre. Three existing methods, namely the fibre quality index (FQI), the spinning consistency index (SCI) and the premium-discount index (PDI) have been considered, and a new method has been proposed based on a multiple-criteria decision-making (MCDM) technique. The efficacy of these methods was determined by conducting a rank correlation analysis between the technological values of cotton and yarn strength. It was found that the rank correlation differs widely for the three existing methods. The proposed method of MCDM (multiplicative AHP) could enhance the correlation between the technological value of cotton and yarn strength.

Key words:

analytic hierarchy process, cotton fibre, fibre quality index, premium-discount index, spinning consistency index, technological value

Introduction

Determining the technological value of cotton fibre is an interesting field of textile research. The quality of final yarn is largely influenced (up to 80%) by the characteristics of raw cotton [1]. However, the level to which various fibre properties influence yarn quality is diverse, and also changes depending on the yarn manufacturing technology. Besides, a cotton may have conflicting standards in terms of different quality criteria. Therefore, the ranking or grading of cotton fibres in terms of different quality criteria will certainly not be the same. This will make the situation more complex, and applying multiple-criteria decision-making (MCDM) methods can probably deliver a plausible solution. The solution must produce an index of technological value or overall quality of cotton fibre, and the index should incorporate all the important fibre parameters. The weights of the fibre parameters should be commensurate with their importance on the final yarn quality.

Traditionally, three fibre parameters have been used to determine the quality value of cotton fibre. These are grade, fibre length and fibre fineness. The development of fibre testing instruments such as the High Volume Instrument (HVI) and the Advanced Fibre Information System (AFIS) has revolutionised the concept of fibre testing. With the HVI it is pragmatically possible to determine most of the quality characteristics of a cotton bale within two minutes. Based on the HVI results, composite indexes such as the fibre quality index (FQI) and spinning consistency index (SCI) can be used to determine the technological value of cotton; this can play a pivotal role in an engineered fibre selection programme [2-3].

In this paper, a new method of determining the technological value of cotton using a multiplicative analytic hierarchy process (multiplicative AHP) of the MCDM method is postulated. The technological value of cotton was also determined by the three traditional methods, namely the fibre quality index (FQI), the spinning consistency index (SCI) and the premium-discount index (PDI). The ranking of cotton fibres produced by these four methods was compared with the ranking of final yarn tenacity, and a rank correlation analysis was carried out.

Overview of MCDM and AHP

Multiple Criteria Decision Making is a well-known branch of Operations Research (OR), which deals with decision problems involving a number of decision criteria and a finite number of alternatives. Various MCDM techniques, such as the weighted sum model (WSM), the weighted product model (WPM), the analytic hierarchy process (AHP), the revised AHP, the technique for order preference by similarity to an ideal solution (TOPSIS), and elimination and choice translating reality (ELECTRE), can be used in engineering decision-making problems, depending upon the complexity of the situation [4-8] The Analytic Hierarchy Process (AHP), introduced by Saaty [9-12], is one of the most frequently discussed methods of MCDM. Although some researchers [13-16] have raised concerns over the theoretical basis of AHP, it has proven to be an extremely useful decision-making method. The reason for AHP's popularity lies in the fact that it can handle the objective as well as subjective factors, and the criteria weights and alternative scores are elicited through the formation of a pair-wise comparison matrix, which is the heart of the AHP.

Details of AHP methodology

Step 1:

Develop the hierarchical structure of the problem. The overall objective or goal of the problem is positioned at the top of the hierarchy, and the decision alternatives are placed at the bottom. Between the top and bottom levels are found the relevant attributes of the decision problem such as criteria and sub-criteria. The number of levels in the hierarchy depends on the complexity of the problem.

Step 2:

Generate relational data for comparing the alternatives. This requires the decision maker to formulate pair-wise comparison matrices of elements at each level in the hierarchy relative to each activity at the next, higher level. In AHP, if a problem involves M alternatives and N criteria, then the decision maker has to construct N judgment matrices of alternatives of $M \times M$ order and one judgment matrix of criteria of $N \times N$ order. Finally, the decision matrix of $M \times N$ order is formed by using the relative scores of the alternatives with respect to each criterion. In AHP, the relational scale of real numbers from 1 to 9 and their reciprocals are used to assign preferences in a systematic manner. When comparing two criteria (or alternatives) with respect to an attribute in a higher level, the relational scale proposed by Saaty [9-12] is used. The scale is shown in Table 1.

Table 1. The fundamental relational scale for pair-wise comparisons

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective.
3	Moderate importance of one over another	Experience and judgment slightly favour one activity over another.
5	Essential or strong importance	Experience and judgment strongly favour one activity over another.
7	Very strong importance	An activity is strongly favoured and its dominance is demonstrated in practice.
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation.
2, 4, 6, 8	Intermediate values between two adjacent judgment	When compromise is needed.
Reciprocals	If activity p has one of the above numbers assigned to it when compared with activity q, then q has the reciprocal value when compared with p.	

Step 3:

In this step, the relative importance of different criteria with respect to the goal of the problem and the alternative scores with respect to each of the criteria is determined. For *N* criteria, the size of the comparison matrix (C_1) will be *N x N*, and the entry c_{ij} will denote the relative importance of criterion *i* with respect to the criterion *j*. In the matrix, $c_{ij} = 1$ if when $i = j$ and $c_{ji} = \frac{1}{c_{ij}}$.

$$C_1 = \begin{bmatrix} 1 & c_{12} & ... & c_{1N} \\ c_{21} & 1 & ... & c_{2N} \\ ... & ... & 1 & ... \\ c_{N1} & c_{N2} & ... & 1 \end{bmatrix}$$

The relative weight or importance of the *i* th criteria (W_i) is determined by calculating the geometric mean (*GM*) of the *i* th row, and then normalising the geometric means of the rows of the above matrix. This can be represented as follows:

$$GM_i = \left\{ \prod_{j=1}^{N} cij \right\}^{\frac{1}{N}} \text{ and } W_i = \frac{GM_i}{\sum_{i=1}^{N} GM_i} \quad (1)$$

Then, matrix C_3 and C_4 are calculated such that $C_3 = C_1 \text{ x } C_2$ and $C_4 = \frac{C_3}{C_2}$, where $C_2 = \left[W_1 \quad W_2 \quad ... \quad W_N \right]^T$.

The principal eigen vector (λ_{max}) of the original pair-wise comparison matrix (C_1) is calculated from the average of matrix C_4. To check the consistency in a pair-wise comparison judgment, the consistency index (*CI*) and consistency ratio (*CR*) are calculated from the following equations:

$$CI = \frac{\lambda_{\max} - N}{N - 1} \text{ and } CR = \frac{CI}{RCI} \quad (2)$$

where *RCI* is the random consistency index; its value could be obtained from Table 2. If the value of *CR* is 0.1 or less, then the judgment is considered to be consistent and acceptable. Otherwise the decision maker has to make some changes in the entry of the pair-wise comparison matrix.

Table 2. RCI values for different numbers of alternative (M)

M	1	2	3	4	5	6	7	8	9
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Similarly, *N* numbers of pair-wise comparison matrices (one for each criterion) of *M x M* order are formed, where each alternative is pitted against all of its competitors, and pair-wise comparison is made with respect to each of the decision criterion. The eigen vector of each of these '*N*' matrices represents the alternative performance scores in the corresponding criterion and from a column of the final decision matrix. The decision matrix appears as follows:

	Criterion				
	C_1	C_2	C_3	…	C_N
Alternative	W_1	W_2	W_3	…	W_N
A_1	a_{11}	a_{12}	a_{13}	…	a_{1N}
A_2	a_{21}	a_{22}	a_{23}	…	a_{2N}
A_3	a_{31}	a_{32}	a_{33}	…	a_{3N}
…	…	…	…	…	…
A_M	a_{M1}	a_{M2}	a_{M3}	…	a_{MN}

Here $\sum_{i=1}^{M} a_{ij} = 1$

Step 4:

In this step, the final priority of all the alternatives is determined considering the alternative scores (a_{ij}) in each criteria and the weight of the corresponding criteria (W_j) using the following equation.

$$A_{AHP} = \max \sum_{j=1}^{N} a_{ij}.W_j \text{ for } i = 1,2,3, \ldots\text{M} \quad (3)$$

Multiplicative AHP

Several researchers have criticized the AHP due to the ranking inconsistencies associated with it [13-16]. The AHP does not necessarily demonstrate the transivity property; i.e. if $A_1 > A_2$ and $A_2 > A_3$ then $A_1 > A_3$. To overcome these problems, Barzilai & Lootsma [17] have proposed a multiplicative variant of AHP. In this approach, the relative performance of the *i* th alternative in terms of the *j* th criterion, i.e. a_{ij} of decision matrix and criteria weights W_j, are not processed according to formula 1. Instead, the following formula is used:

$$R\left[\frac{A_K}{A_L}\right] = \prod_{j=1}^{N}\left[\frac{a_{Kj}}{a_{Lj}}\right]^{W_j} \quad (4)$$

where a_{Kj} and a_{Lj} are the scores of alternative K and L on the *j* th criterion, and W_j is the weightage of the *j* th criterion. If $R\left[\frac{A_K}{A_L}\right]$ >1 then A_K is more desirable than A_L (in the maximisation case). One can use a variant of the above formula to compute the preference values, which can in turn be used to rank alternatives:

$$Pi = \prod_{j=1}^{N}\left(a_{ij}\right)^{W_j} \quad (5)$$

The ranking produced by the multiplicative AHP is very robust and immune to ranking inconsistencies. Moreover, the ranking produced by this method remains independent of the method of normalisation. Therefore, the test results obtained from the HVI or AFIS can be used directly in equation 5 without any normalization [18]. Here the W_j will have a negative sign for the cost criterion, which has a negative impact on the overall objective.

Traditional Models to Determine the Technological Values of Cotton

Fibre quality index (FQI)

This is probably the most widely used method to determine the technological value of cotton [19-22]. The main reason for its popularity may be attributed to the simplicity of the equation used. Several variants of the FQI model are available. In this work we have used the following form of FQI proposed by the South Indian Textile Research Association [21].

$$FQI = \frac{L.UR.FS.M}{FF} \quad (6)$$

where *L* is 2.5% span length, *UR* is the uniformity ratio, *FS* is the fibre bundle tenacity, *M* is the maturity coefficient, and *FF* is the fibre fineness (micronaire). If the HVI mode of fibre testing is used, then the above expression is changed as follows:

$$FQI_{HVI} = \frac{UHML.UI.FS}{FF} \quad (7)$$

where FQI_{HVI} is the HVI quality index, *UHML* is the upper half mean length and *UI* is the uniformity index.

Spinning consistency index (SCI)

This is a calculation for predicting the overall quality and spinnability of the cotton fibre. It is chiefly used to gain within and between lay-down consistencies of major cotton properties. The regression equation of SCI uses most of the individual HVI measurements, and it is based on the five-year crop average of U. S. Upland and Pima cotton. The regression equation [23] used to calculate SCI is as follows:

$$SCI = -414.67 + 2.9FS + 49.17UHML + 4.74UI - 9.32FF + 0.65Rd + 0.36(+b) \quad (8)$$

where Rd is the reflectance degree and +b is the yellowness of cotton fibre.

Premium-Discount Index (PDI)

This method was proposed by Mogazhy et al. [24]. It includes the development of a multiple regression equation relating fibre properties and yarn strength, the determination of the percentage contribution of fibre properties to yarn strength, the selection of a reference set of cotton properties, the determination of a difference factor between the fibre property and the reference set, and finally the development of a premium-discount formula. The regression equation of the following form is developed from the available fibre and yarn data.

$$Yarn\ Tenacity = C_1 + C_2FS + C_3FE + C_4UHML + C_5UI + C_6SFC + C_7FF \quad (9)$$

where $C_1, C_2, \ldots C_7$, are the regression coefficients, *FE* is the fibre breaking elongation in percentage, and *SFC* is the short fibre content as measured by AFIS. The regression coefficients are dependent on the scales of measurement, and therefore cannot be used as a measure of their importance. To overcome this problem, 'β' coefficients of the variables are determined using the standardised variables in the regression equation. The relative contribution of the *i* th fibre property can be determined by the following equation:

$$C_i\% = 100\left(\frac{B_i}{\sum_{i=1}^{N} B_i}\right)R^2 \quad (10)$$

where B_i is the 'β' coefficient of the *i* th variable, *N* is the number of HVI fibre properties and R^2 is the coefficient of determination.
The reference set is expressed in terms of the average and standard deviation of a fibre property. In the next step, the relative difference factor for each cotton fibre is determined by the following equation:

$$D_i = \frac{(x_i - \mu_i)}{\sigma_i} \quad (11)$$

where x_i is the *i* th fibre property of a cotton, μ_i and σ_i are the overall average and standard deviation of all the cottons in the *i* th property.
Now, based on the percentage contribution of fibre property $C_i\%$ and the difference factor D_i, the premium-discount index (PDI) could be calculated using the following equation:

$$PDI = \sum_{i=1}^{N} (C_i . D_i) \quad (12)$$

Here the sign of the product in the summation should follow the sign of the variable as obtained in the regression equation.

Material and Methods

Data collection and analysis

Each year the International Textile Centre (USA) conducts a crop study for different varieties of cotton. The results of the crop study of 1997 and 1998, which includes 33 sets of fibre and yarn data for two different yarn counts (22 Ne and 30 Ne), were used in our investigation. We ranked the 33 cotton fibres according to their FQI, SCI, PDI and multiplicative AHP (MI_{AHP}) values. We also ranked the 33 cottons according to the final yarn tenacity. Separate rankings were obtained for 22 Ne and 30 Ne. The difference between the two rankings (fibre quality ranking and yarn tenacity ranking) was calculated to measure the rank correlation coefficient between them by using the following equation.

$$R_s = 1 - \frac{6\sum d^2}{M(M^2 - 1)} \qquad (13)$$

where R_s is the rank correlation, d is the absolute difference between the two rankings, and M is the total number of alternatives (33). The summary statistics of fibre properties are given in Table 3.

Table 3. Summary statistics of cotton fibre properties

Fibre Properties	Minimum	Maximum	Mean	Standard deviation
Fibre bundle tenacity, cN/tex	26.5	34.0	29.05	1.477
Fibre elongation, %	5.3	6.9	6.27	0.458
UHML, inch	0.97	1.20	1.06	0.047
Uniformity index	79.2	83.2	81.57	0.971
Short Fibre Content	5.6	18.4	9.77	3.043
Micronaire	3.1	5.0	4.23	0.453

Hierarchy formulation for multiplicative AHP

The goal or objective of the present investigation is to determine the technological value of cotton, which should reflect the achievable level of yarn quality (yarn strength). In general, the cotton fibre criteria of this problem can be classified under three headings, namely tensile properties, length properties and fineness properties. Tensile properties can be divided into two sub-criteria, fibre bundle tenacity (*FS*) and elongation (*FE*). Similarly, UHML, UI and SFC are the relevant sub-criteria of length properties to be considered here. Fineness is solely represented by the micronaire (*FF*) value of cotton. At the lowest level of the hierarchy, there are 33 cotton fibre alternatives, which should be ranked according to their technological value. The schematic representation of the problem is depicted in Figure 1.

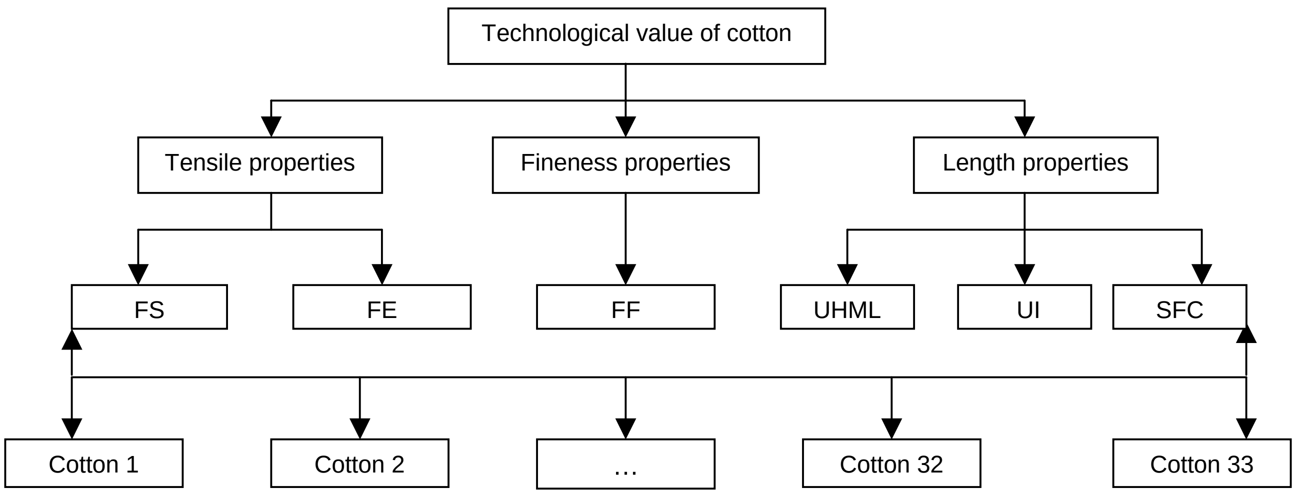

Figure 1. Hierarchical structure of cotton fibre quality

Determination of criteria weights

With respect to the overall objective problem, the pair-wise comparison matrix of three criteria is given in Table 4. Here the comparisons are made according to Saaty's scale given in Table 1.

Table 4. Pair-wise comparison matrix of criteria with respect to objective

Criteria	Tensile	Length	Fineness	GM	Normalized GM
Tensile	1	1/2	3	1.145	0.309
Length	2	1	5	2.154	0.581
Fineness	1/3	1/5	1	0.406	0.110

It can be inferred from Table 4 that tensile properties moderately predominate over the fineness properties. However, the length properties demonstrate a strong preponderance over the fineness properties. The dominance of length properties over the tensile properties is between equal to moderate. The normalised *GM* column of Table 4 indicates that the length properties of cotton fibres have the most dominant influence with a relative weight of 0.581. The relative weights of tensile and fineness properties are 0.309 and 0.110 respectively. For the measurement of consistency of judgment, the original matrix is multiplied by the weight vector to obtain the product as shown below:

$$\begin{bmatrix} 1 & 1/2 & 3 \\ 2 & 1 & 5 \\ 1/3 & 1/5 & 1 \end{bmatrix} * \begin{bmatrix} 0.309 \\ 0.581 \\ 0.110 \end{bmatrix} = \begin{bmatrix} 0.930 \\ 1.749 \\ 0.329 \end{bmatrix}$$

Now, $\lambda \max = (\frac{0.930}{0.309} + \frac{1.749}{0.581} + \frac{0.329}{0.110}) / 3 = 3.004$

Therefore, $CI = \frac{3.004 - 3}{3 - 1} = 0.002$ and $CR = \frac{CI}{RCI} = \frac{0.002}{0.58} = 0.003$ < 0.1 (acceptable)

The next step is concerned with finding the relative weights of various sub-criteria (Level 3) with respect to the corresponding criteria (Level 2). The pair-wise comparison between the sub-criteria of tensile and length properties and the derived weight vectors are shown in Tables 5 and 6 respectively. Then the global weights of sub-criteria are calculated by multiplying the relative weight of a sub-criterion with respect to the corresponding criterion and the relative weight of that criterion with respect to the objective. For example, the global weight of tenacity is 0.875 x 0.309 = 0.270. For tenacity, elongation, *UHML*, *UI*, *SFC* and *FF*, the values of global weights are 0.270, 0.039, 0.291, 0.145, 0.145 and 0.110 respectively.

Table 5. Pair-wise comparison of sub-criteria with respect to tensile properties

Tensile properties	Tenacity	Elongation	Normalised GM
Tenacity	1	7	0.875
Elongation	1/7	1	0.125

CR = 0

Table 6. Pair-wise comparison of sub-criteria with respect to length properties

Length properties	UHML	UI	SFC	Normalised GM
UHML	1	2	2	0.500
UI	1/2	1	1	0.250
SFC	1/2	1	1	0.250

CR = 0

Therefore, according to the multiplicative AHP model, the equation to calculate the technological value of cotton (MI_{AHP}) is as follows:

$$MI_{AHP} = \frac{FS^{0.27}.FE^{0.039}.UHML^{0.291}.UI^{0.145}}{FF^{0.11}.SFC^{0.145}} \quad (14)$$

Determination of premium-discount index formula

The % contribution of various cotton properties on the ring yarn tenacity was determined separately for 22 Ne and 30 Ne, using the method described earlier. The results are shown in Table 7. The negative sign associated with *UHML* is unexpected, and may be ascribed to the prevailing autocorrelation among the fibre properties. The R^2 values of the multiple regression equation were 0.745 and 0.676 for 22 Ne and 30 Ne respectively. The resultant formula to calculate the premium-discount index of cotton fibre is as follows:

$$PDI = 22.15D_{FS} - 4.75D_{FE} - 4.37D_{UHML} + 11.19D_{UI} - 20.78D_{SFC} - 7.8D_{FF} \quad (15)$$

where D_{FS}, D_{FE}, …..are the difference factors for fibre tenacity, fibre elongation etc.

Table 7. Contribution of fibre properties to ring yarn tenacity

Fibre property	Yarn count (22 Ne)	Yarn count (30 Ne)	Average
Fibre tenacity	21.47	22.83	22.15
Fibre elongation	-4.61	-4.89	-4.75
Upper half men length	-4.16	-4.59	-4.37
Uniformity index	7.55	14.83	11.19
Short fibre content	-27.94	-13.62	-20.78
Fibre fineness	-8.77	-6.84	7.80

Results and Discussion

The technological value of cotton fibre derived by various methods, as well as the rank correlation coefficient (R_s) between the technological value of cotton and yarn tenacity, are shown in Tables 8 and 9. It is observed that the R_s ranges from a very low value of 0.098 to a very high value of 0.817. In general, the R_s values were the lowest for the FQI model and highest for the PDI model. The proposed multiplicative AHP model, which can be considered as a variant of the traditional FQI model, demonstrates a reasonably good R_s value of 0.738 and 0.716 for 22 Ne and 30 Ne respectively. The SCI model shows a moderate R_s value of 0.401 and 0.459 for 22 Ne and 30 Ne respectively.

The traditional FQI model is basically a multiplicative model where all the criteria weights (W_j) are considered to be unity. However, in practice this assumption is totally void, as the influence of various fibre properties on yarn properties will not be identical. Therefore, in a multiplicative type model, proper emphasis must be given to the weights of different decision criteria. This modification is introduced here in the multiplicative AHP model resulting in enhanced R_s values.

From Table 9, one may be tempted to conclude that in the given problem, the premium-discount index is the best method to determine the technological value of cotton. However, in the premium-discount index model, the decision maker receives a clear idea of the influence of fibre properties on yarn tenacity from the standardised 'β' coefficient values. The real accuracy of the premium-discount index model can be judged by subjecting it to some new test samples, which were not used for developing the regression equation relating the fibre properties and yarn tenacity. In case of the multiplicative AHP model, the relative weights of the cotton fibre properties are obtained from the pair-wise comparison matrix, where entries were made based on the past experience of the decision maker, without having any specific knowledge of the present case. Therefore, the multiplicative AHP is a very flexible tool, and can be used in any situation where the decision-maker has some prior knowledge of the problem.

Table 8. Cotton fibre properties and the technological values

Sample No	FS	FE	UHML	UI	SFC	FF	FQI	SCI	PDI	MI_{AHP}
1	28.7	6.5	1.09	81	13.8	4.4	575.9	119.9	-47.5	2.998
2	28.5	6.6	1.15	80.2	11.9	3.5	751.0	125.7	-37.7	3.182
3	28.7	5.7	1.1	79.2	18.4	3.7	675.8	118.9	-80.1	2.915
4	30.8	6.4	1.13	82.6	9.8	4.3	668.6	133.6	28.8	3.261
5	26.5	5.8	1.09	81.5	8.4	3.8	619.5	120.6	-20.2	3.193
6	27.5	6.3	1.07	82.8	8.4	4.5	541.4	120.6	-5.6	3.167
7	29.2	5.3	0.98	80	16.6	4.5	508.7	109.2	-49.7	2.809
8	29	6.7	1.05	81.9	10.9	4.2	593.8	124.3	-7.7	3.102
9	30.3	6.7	1.1	83.2	8.7	4.4	630.2	134.3	33.7	3.278
10	28.1	6.3	1.01	80.7	15.5	3.8	602.7	117.5	-51.6	2.909
11	30.6	6.6	1.07	83.1	9	4.7	578.9	130.1	33.6	3.219
12	28.7	6.7	1.05	81	11.8	3.9	625.9	120.2	-23.5	3.078
13	28.3	6.5	0.97	81.5	13.1	3.8	588.8	118.3	-21.4	2.959
14	29	6.6	1.06	80.7	11.3	3.1	800.2	129.1	-5.1	3.191
15	27.7	5.5	1.05	81.5	11.7	4.7	504.3	110.5	-33.5	2.970
16	29.1	6.1	1.05	81.7	11.2	4	624.1	123.9	-0.8	3.097
17	28.6	5.7	1.04	82.4	10.8	4.2	583.5	125.0	4.1	3.069
18	28.8	5.5	1.05	82.6	9.2	4.1	609.2	126.2	23.2	3.161
19	28.1	6.7	1.03	81.7	7.2	4.5	525.5	116.8	-1.5	3.223
20	29	6	1.04	81.4	6.8	5	491.0	114.0	8.9	3.233
21	31.7	6.3	1.03	80.6	8.9	3.7	711.3	131.0	46.2	3.284
22	29.3	6	1.03	81.2	8.1	4.4	556.9	119.9	13.5	3.195
23	29.1	6.9	1.05	83.2	5.6	4.6	552.6	128.0	36.0	3.398
24	30.8	6.4	1.01	81.7	6.8	3.7	686.9	132.0	60.5	3.378
25	26.7	6.9	1.04	82.6	7.5	4.8	477.8	111.7	-22.4	3.155
26	30.2	6.7	1.06	82.3	5.6	4.3	612.7	128.9	48.5	3.457
27	28.7	6.2	1.02	80.7	8.7	3.8	621.7	120.1	3.9	3.188
28	29.5	6.4	1.02	81.9	7.2	4.8	513.4	116.3	20.6	3.228
29	27.5	6.9	1.01	81.7	9.7	4.5	504.3	110.9	-27.8	3.054
30	28.9	6	1.07	81.1	7.7	4.6	545.2	116.3	1.9	3.226
31	30.3	6.1	1.1	80.6	8.4	4.6	584.0	121.7	8.6	3.252
32	34	6.6	1.2	82.8	6.8	3.8	889.0	155.6	99.7	3.649
33	26.8	5.3	1	80.8	6.8	4.9	441.9	101.7	-18.3	3.117

Table 9. Rank correlation value between the technological value of cotton and yarn tenacity

Technological value model	Yarn count	
	22 Ne	30 Ne
FQI_{HVI}	0.098	0.129
SCI	0.401	0.459
PDI	0.817	0.809
MI_{AHP}	0.738	0.716

Conclusions

A new multiplicative AHP model has been proposed to determine the technological value of cotton. The proposed method uses a variant of the traditional FQI formula, and enhances the rank correlation between the technological value of cotton and yarn tenacity. The incorporation of proper weights of cotton properties in the multiplicative formula is more logical than having the same weight for all the cotton properties. The past experience of the decision-maker plays a key role in determining the criteria weights in the proposed multiplicative AHP method. Of the four methods considered here, the premium-discount index method shows maximum rank correlation between the technological value of cotton and yarn tenacity. The multiplicative AHP, SCI and FQI models are the remaining three methods, in the order of descending rank correlation. Similar studies could also be initiated using other MCDM methods.

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