

A new algorithm of cotton fibre selection and laydown using TOPSIS method of multi-criteria decision making

Abhijit Majumdar^a

Government College of Engineering & Textile Technology, Berhampore 742 101, India

Bijan Sarkar

Department of Production Engineering, Jadavpur University, Kolkata 700 032, India

and

Prabal Kumar Majumdar

Government College of Engineering & Textile Technology, Serampore 712 201, India

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A novel approach of cotton fibre grading and selection has been proposed by using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method of Multi-Criteria Decision Making (MCDM). Cotton bales were grouped into different categories based on their quality values determined by TOPSIS method and Spinning Consistency Index (SCI). Laydowns were then formed by random and frequency relative picking algorithms from 1200 real cotton bales with known HVI properties. Computer simulation results demonstrate that the frequency relative picking of TOPSIS and SCI are capable to reduce the between laydown variability of major cotton properties.

Keywords: Cotton, Frequency relative picking, Multi-criteria decision making, Random picking, Spinning consistency index, TOPSIS

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1 Introduction

The major challenge of yarn engineering is not only to produce yarns having customer-defined characteristics but also to minimize the variability of yarn properties over a period of time. Cotton fibre is generally having enormous variability of attributes between and within the bales. Besides, the characteristics of spun yarns are decisively influenced by the properties of constituent cotton.^{1,2} Hence, there must be an ingenious algorithm of cotton fibre grading and selection to cope with the high variability of fibre properties and to ensure consistency in laydown averages and yarn properties. In recent years, the revolutionary development of High Volume Instrument (HVI) and Advanced Fibre Information System (AFIS) have paved the way for yarn engineering as these instruments are apt to measure several fibre properties at a very fast pace. Therefore, the spinner gets ample opportunity to evaluate each and every bale based on the objective results of cotton characteristics.

In general, two algorithms, namely Random Picking (RP) and Frequency Relative Picking (FRP), are prevalently used in the spinning mills for the laydown formation of cotton bales. Mogahzy and Gawayed^{3,4} expatiated on the mathematical foundations of random and frequency relative picking methods. They demonstrated that the population variability, number of category, category break point location and laydown size are the factors influencing the cotton mix variability. It must be considered here that if the bales are categorized based on the individual cotton properties then the number of cotton groups in the warehouse will be huge and pragmatically unmanageable. Mathematically, the number of cotton groups in the warehouse will be X^Y , where X is the number of levels used for a single cotton property and Y , the number of properties considered. To simplify this intricacy an overall quality index, which should encompass all the major attributes of cotton fibre, should be used. Fibre Quality Index (FQI) and its variants are probably the oldest and most popularly used quality index of cotton fibre.⁵⁻⁷ Kang *et al.*⁸ have demonstrated that FQI can reduce the between laydown variances of individual fibre properties. El Mogahzy *et al.*⁹ proposed a

^aTo whom all the correspondence should be addressed.
E-mail: abhitextile@rediffmail.com

premium-discount index for the grading of cotton with respect to yarn strength. United States Department of Agriculture (USDA) has developed a multiple regression equation to determine the Spinning Consistency Index (SCI) of cotton, which is able to control within and between laydown variances.^{10,11}

In this work, a new algorithm has been proposed to determine the quality value of cotton fibre using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach of Multi-Criteria Decision Making (MCDM). Bales were categorized into different groups based on the TOPSIS value of cotton, and laydown was formed using frequency relative picking algorithm. The range and variance of laydown mean of fibre properties were determined and the results were compared with those of random picking and frequency relative picking of SCI.

2 Overview of Multi-Criteria Decision Making

The problem of MCDM involves a set of M alternatives ($i = 1, 2, \dots, M$) which have to be ranked with respect to a set of N criteria or attributes ($j = 1, 2, \dots, N$). Various MCDM techniques, such as Weighted Sum Model (WSM), Weighted Product Model (WPM), the Analytic Hierarchy Process (AHP), revised AHP, TOPSIS and Elimination and Choice Translating Reality (ELECTRE), can be used in engineering decision making problems, depending upon the nature and complexity of the situation. The AHP is one of the most popular methods of MCDM. The reason behind the popularity of AHP lies in the fact that it can handle objective as well as subjective factors and the criteria weights and alternative scores are elicited through the formation of pair-wise comparison matrix, which is the heart of the AHP. However, the total number of pair-wise comparisons in a decision problem having M alternatives and N criteria is expressed by the following equation.

$$\frac{N(N-1)}{2} + N \cdot \frac{M(M-1)}{2} \quad \dots(1)$$

This may be unmanageable where a huge number of decision criteria and alternatives are involved. The TOPSIS is more potent in handling the tangible attributes and there is no limit in terms of number of criteria or alternative.

The three main steps of MCDM are as follows:

- (i) Determining the goal, relevant criteria and alternatives of the decision problem.

- (ii) Attaching numerical weights to the relative importance of the criteria.
- (iii) Processing the numerical values of alternative scores to determine the ranking of each alternative.

2.1 The TOPSIS Methodology

The TOPSIS was developed by Hwang and Yoon.¹² The basic philosophy of this method is that the selected alternative should have shortest distance from the ideal solution and longest distance from the worst solution in a geometrical sense. First, the relevant objective or goal, decision criteria and alternatives of the problem are identified. Then the decision matrix is formulated which is based on the information available regarding the problem. If the number of alternatives is M and the number of criteria is N , then the decision matrix having an order of $M \times N$ can be represented as follows:

$$D_{M \times N} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1N} \\ a_{21} & a_{22} & \dots & a_{2N} \\ \dots & \dots & \dots & \dots \\ a_{M1} & a_{M2} & \dots & a_{MN} \end{bmatrix}$$

where an element a_{ij} of the decision matrix $D_{M \times N}$ represents the actual value of the i th alternative in terms of j th criteria. The decision matrix is converted to normalized decision matrix, so that the scores obtained in different scales become comparable. An element r_{ij} of the normalized decision matrix R can be calculated by the following equation:

$$r_{ij} = \frac{a_{ij}}{\left[\sum_{i=1}^M (a_{ij})^2 \right]^{0.5}} \quad \dots(2)$$

The normalized matrix is then converted to weighted normalized matrix by multiplying each column of the normalized decision matrix R with the associated criteria weight. Hence, an element v_{ij} of weighted normalized matrix V is represented as follows:

$$v_{ij} = r_{ij} \cdot W_j \quad \dots(3)$$

The criteria weights can be determined by the AHP, which is explained in the next section. The next step produces the positive ideal (A^*) and negative ideal (A^-) solutions in the following manner:

$$A^* = \left\{ \begin{array}{l} (\max v_{ij} | j \in J), (\min v_{ij} | j \in J') \\ \text{for } i = 1, 2, 3, \dots, M \end{array} \right\}$$

$$= \{v_1^*, v_2^*, \dots, v_N^*\}$$

$$A^- = \left\{ \begin{array}{l} (\min v_{ij} | j \in J), (\max v_{ij} | j \in J') \\ \text{for } i = 1, 2, 3, \dots, M \end{array} \right\}$$

$$= \{v_1^-, v_2^-, \dots, v_N^-\}$$

$$\text{where } J = \left\{ \begin{array}{l} j = 1, 2, \dots, N \mid j \text{ associated with benefit} \\ \text{or positive criteria} \end{array} \right\}$$

$$\text{and } J' = \left\{ \begin{array}{l} j = 1, 2, \dots, N \mid j \text{ associated with cost} \\ \text{or negative criteria} \end{array} \right\}$$

For the benefit criteria, the decision maker prefers the maximum value among the alternatives. Therefore, A^* indicates the positive ideal solution and A^- , the negative ideal solution. Then the N dimensional Euclidean distance method is applied, as shown below, to measure the separation distances of each alternative from A^* and A^- :

$$S_i^* = \left\{ \sum_{j=1}^N (v_{ij} - v_j^*)^2 \right\}^{0.5}, i = 1, 2, \dots, M$$

and

$$S_i^- = \left\{ \sum_{j=1}^N (v_{ij} - v_j^-)^2 \right\}^{0.5}, i = 1, 2, \dots, M \quad \dots(4)$$

where S_i^* and S_i^- are the separation distances of alternative i from A^* and A^- respectively.

Finally, the relative closeness (C_i^*) value of each alternative to the ideal solution is determined using the following equation; the value of C_i^* lies within the range from 0 to 1:

$$C_i^* = \frac{S_i^-}{(S_i^* + S_i^-)} \quad \dots(5)$$

The alternative having the maximum C_i^* is the most preferred one and vice versa.

2.2 The AHP Methodology

The AHP was developed by Saaty^{13,14} as a very potent tool of MCDM. Recently, AHP has been used

to solve the problem of cotton bale management and grading.^{15, 16} In AHP, a pair-wise comparison matrix of attributes is constructed using a scale of relative importance. An attribute compared to itself or with any other attribute having the same importance is always assigned the value 1 and therefore the main diagonal entries of the pair-wise comparison matrix are all 1. The numbers 3, 5, 7 and 9 correspond to the verbal judgments of 'moderate importance', 'strong importance', 'very strong importance' and 'absolute importance' respectively (with 2, 4, 6 and 8 for compromise between the previous values).

For N criteria, the size of this comparison matrix will be $N \times N$ and the entry c_{ij} will denote the comparative importance of criterion i with respect to criterion j . In the matrix, $c_{ij} = 1$ when $i = j$ and $c_{ij} = 1/c_{ji}$. The pair-wise comparison matrix (C_1) of criteria is shown below:

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

The principle eigen vector of the above matrix represents the relative weights of the decision criteria. The relative weight of the i th criteria (W_i) is determined by calculating the geometric mean of the i th row (GM_i) of the above matrix and then normalizing the geometric means of rows. This can be represented as follows:

$$GM_i = \left\{ \prod_{j=1}^N c_{ij} \right\}^{\frac{1}{N}} \text{ and } W_i = \frac{GM_i}{\sum_{i=1}^N GM_i} \quad \dots(6)$$

Matrix C_3 and C_4 are then calculated using the following relationships: $C_3 = C_1 \times C_2$ and $C_4 = C_3 / C_2$,

$$\text{where } C_2 = [W_1 \ W_2 \ \dots \ W_N]^T.$$

The maximum eigen value ($\lambda_{\max}$) of the original pair-wise comparison matrix (C_1) is calculated from the average of matrix C_4 . To check the consistency of pair-wise comparison, consistency index (CI) and consistency ratio (CR) are calculated using the following equations:

$$CI = \frac{\lambda_{\max} - N}{N - 1} \text{ and } CR = \frac{CI}{RCI} \quad \dots(7)$$

where *RCI* is random consistency index and its value can be obtained from Table 1. If the value of *CR* is 0.1 or less, then the judgment is considered to be consistent.

3 Materials and Methods

3.1 Data Collection and Analysis

HVI test results of 1200 cotton bales were collected from a reputed spinning mill of northern India. It is assumed that 1200 bales will be consumed over a span of 30 days forming one laydown each day. Therefore, 40 bales must be chosen daily from the existing population of bales. The range of HVI properties are shown in Table 2. *SCI* values of 1200 bales were determined using the following regression equation:

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

where *FS*, *UHML*, *UI*, *FF*, *Rd* and *+b* are the bundle tenacity, upper half mean length, uniformity index, fineness (micronaire), reflectance degree and yellowness of cotton fibre respectively.

The distribution pattern of *SCI* value of bales is depicted in Fig. 1. From the distribution of *SCI*, bales were grouped into 8 categories. The number of bales in different categories from group no. 1 to group no. 8 was 30, 90, 180, 210, 330, 270, 60 and 30 respectively. It should be noted that the number of bales in each category is a multiple of 30, as the sampling fraction was 40/1200= 1/30. This ensures that the number of bales picked from each category will be an integer.

3.2 Formation of Decision Hierarchy and Determination of Criteria Weights

In this study, the weights of decision criteria were determined using the AHP. Here, the goal or objective (level 1) was the overall quality of cotton fibre with respect to yarn strength, which receives maximum attention from the spinners. The decision criteria of this present problem, i.e. tensile properties, length properties and fineness properties, are placed at level 2. At level 3, sub-criteria are placed. Tensile properties can be divided into two sub-criteria, i.e. bundle tenacity (*FS*) and breaking elongation (*FE*). Similarly, *UHML*, *UI* and Short Fibre Index (*SFI*) are the relevant sub-criteria of length properties. Fineness is solely represented by the micronaire value of cotton. The schematic representation of the decision hierarchy is depicted in Fig. 2.

Table 1— RCI values for different number of criteria (N)

N	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

Table 2— Summary statistics of cotton fibre properties

Fibre property	Mean	Maximum	Minimum	CV %
Bundle tenacity cN/tex	27.63	30.20	24.50	3.44
Elongation, %	5.95	7.75	3.81	13.34
UHML, mm	26.20	28.90	23.56	2.87
Uniformity index	81.18	84.22	78.46	0.92
Short fibre index	8.86	15.10	4.30	21.60
Micronaire	4.28	5.50	3.21	8.72
SCI	110.47	128.60	89.60	6.78

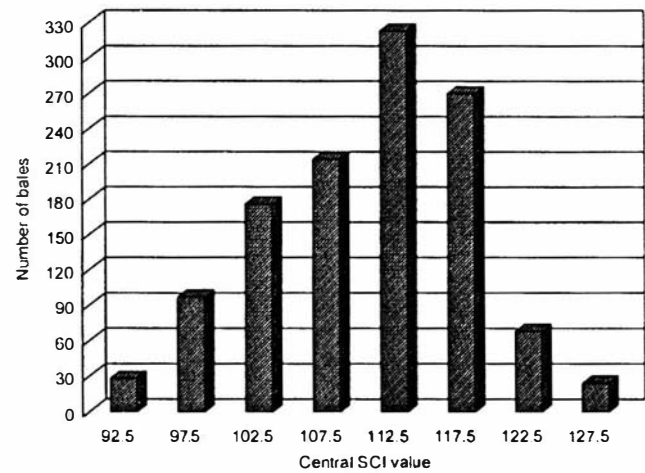


Fig. 1—Distribution pattern of *SCI* values of cotton bales

The pair-wise comparison matrix of the three decision criteria with respect to the overall objective of the present problem is given in Table 3. The normalized GM column indicates that the length properties of cotton fibres have the most dominant influence on yarn strength 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 get the product as shown below:

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

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

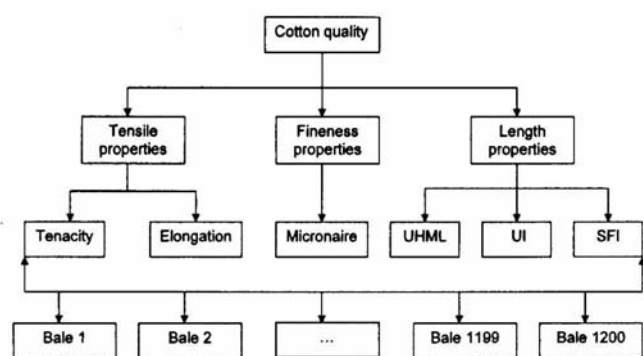


Fig. 2—Hierarchical structure of cotton fibre quality

Table 3—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

Therefore,

$$CI = \frac{3.004 - 3}{3 - 1} = 0.002$$

and

$$CR = \frac{CI}{RCI} = \frac{0.002}{0.58} = 0.003 < 0.1$$

As the value of CR is well below 0.1, the comparison matrix is consistent.

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 are shown in the following two matrices:

$$\begin{matrix} FS & FE \\ FS & \begin{bmatrix} 1 & 7 \\ 1/7 & 1 \end{bmatrix} \end{matrix} \text{ and } \begin{matrix} UHML & UI & SFI \\ UHML & \begin{bmatrix} 1 & 2 & 2 \\ 1/2 & 1 & 1 \\ 1/2 & 1 & 1 \end{bmatrix} \end{matrix}$$

The relative weights of FS and FE with respect to tensile properties of cotton are 0.875 and 0.125 respectively. Similarly, the relative weights of $UHML$, UI and SFI with respect to length properties of cotton are 0.5, 0.25 and 0.25 respectively. Then the

global weights of sub-criteria with respect to objective 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, global weight of FS is $0.875 \times 0.309 = 0.270$. For FS , FE , $UHML$, UI , SFI and FF the values of global weights are 0.270, 0.039, 0.291, 0.145, 0.145 and 0.110 respectively. The TOPSIS value of the bales was determined using the method as described earlier. Then another arrangement of 1200 bales was made according to the ascending order of TOPSIS. Similar categories of bales were made from TOPSIS arrangement as it was done in case of SCI . The bales were chosen according to random and frequency relative picking algorithms from both the SCI and TOPSIS arrangements.

3.3 Random Picking Algorithm

In random picking (RP), bales are chosen purely on random basis irrespective of their properties. If the population size is N and the number of bales in each laydown is n , then the number of possible combination at the beginning can be expressed by the following equation:

$${}^N C_n = \binom{N}{n} = \frac{N!}{n!(N-n)!} \quad \dots(9)$$

Therefore, the possible number of ways or runs (P) in which the population N can be consumed is expressed by the following equation:

$$P = \binom{N}{n} \cdot \binom{N-n}{n} \cdot \binom{N-2n}{n} \cdots \binom{n}{n} \quad \dots(10)$$

Hence, the probability of obtaining any particular run will be as follows:

$$P^{-1} = \left[\binom{N}{n} \cdot \binom{N-n}{n} \cdot \binom{N-2n}{n} \cdots \binom{n}{n} \right]^{-1} \quad \dots(11)$$

Here, P is a huge number and involves rigorous calculations. Therefore, a computer programme was developed using the 'C language', so that a laydown of 40 bales is formed daily using random picking algorithm and the laydown mean of fibre properties and within laydown variances are calculated automatically. Once a bale is picked for a particular laydown, its identification number is deleted from the population to prevent the double picking.

3.4 Frequency Relative Picking Algorithm

In frequency relative picking (FRP), cotton bales belonging to a certain category represent the laydown in numbers proportional to the relative frequency of that category in the population. The number of bales picked from each category is determined by the following equation:

$$n_p = n \cdot \frac{N_p}{N} \quad \dots(12)$$

where n_p and N_p are the number of bales picked daily from category p and total number of bales in category p respectively. As the groups are non-overlapping, in case of frequency relative picking algorithm $\sum_{p=1}^{p=r} n_p = n$ and $\sum_{p=1}^{p=r} N_p = N$, where r is the number of categories into which the bales are grouped.

The total number of runs (P_{FRP}) in case of FRP can be expressed by the following equation:

$$P_{FRP} = \prod_{p=1}^{p=r} \binom{N_p}{n_p} \binom{N_p - n_p}{n_p} \binom{N_p - 2n_p}{n_p} \dots(13)$$

In this study, the bales were divided into 8 categories and in FRP 1, 3, 6, 7, 11, 9, 2, and 1 number of bales have to picked daily from the group no. 1 to group no. 8 respectively to form the laydown of 40 bales. Another computer programme was developed using ‘C language’ to select bales from various categories in accordance with the FRP algorithm and to obtain the laydown mean and within laydown variances of various fibre properties. Between laydown variances were then calculated from the mean of 30 laydowns, which basically completes one simulated run of bale consumption.

4 Results and Discussion

In this investigation, the simulated run of laydown formation and bale consumption was repeated for 10 times for each bale picking algorithm (RP & FRP) and arrangement (SCI & TOPSIS). When RP is employed, ideally the results should be the same irrespective of SCI and TOPSIS arrangement. However, some differences in the results are noticed as the simulated run was repeated for limited number of occasions. For comparing the results of different algorithms, the average of 10 simulated runs was taken.

4.1 Improvement in Range of Laydown Mean

Table 4 shows the range of laydown mean of various fibre properties. The entries here represent the average of 10 simulated runs. It is noted that the range of laydown mean is consistently lower in case of FRP as compared to that in case of RP. The % reduction in the range of laydown mean with respect to the average of RP is shown within brackets corresponding to the rows of FRP. In case of FRP of SCI, the reduction in range for bundle tenacity, UHML and micronaire is 15.40% (from 0.617 to 0.522), 23.55% (from 0.501 to 0.383) and 16.17% (from 0.235 to 0.197) respectively. The improvement is more striking (78.28%), as expected, in case of SCI as it was the categorizing criterion for the bales. In comparison, the reduction in range of bundle tenacity, UHML and micronaire for FRP of TOPSIS is 9.08%, 24.95% and 51.91% respectively. Therefore, it seems that the FRP of TOPSIS exerts better control on the micronaire than the FRP of SCI. In case of FRP of TOPSIS, the range of laydown mean of categorizing criterion shows a reduction of 81.43%, which is comparable with FRP of SCI.

Figure 3 depicts the range of laydown mean of SCI in different simulation runs. It is observed that the

Table 4— Comparison of range of laydown mean

Bale picking algorithm	Fibre property			SCI/ TOPSIS
	Tenacity	UHML	Micronaire	
RP of SCI	0.598	0.492	0.238	4.305
RP of TOPSIS	0.635	0.509	0.232	0.070
RP average	0.617	0.501	0.235	4.305/ 0.070
FRP of SCI	0.522	0.383	0.197	0.935
	(15.40)	(23.55)	(16.17)	(78.28)
FRP of TOPSIS	0.561	0.376	0.113	0.013
	(9.08)	(24.95)	(51.91)	(81.43)

Values in the parentheses indicate percentage reduction with respect to RP average

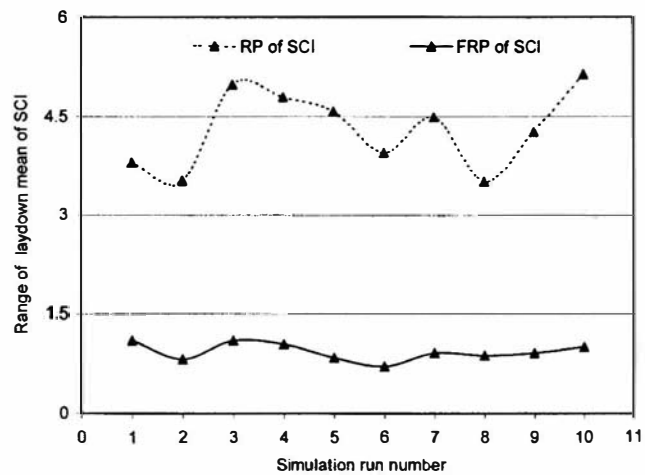


Fig. 3—Range of laydown mean of SCI in different runs

range of laydown mean of SCI reduces significantly and becomes very consistent when the bales are chosen on the basis of FRP of SCI. It is also observed that in RP the maximum range of SCI (5.145) is produced in the 10th run. In this particular run, the mean SCI values of 10th and 17th laydowns are 113.147 and 108.002 respectively, resulting in such a huge range. It is perceived that the yarns produced from these laydowns will differ widely in their qualities, which is undesirable. In contrast, the FRP of SCI shows the maximum range of laydown mean of SCI in the 3rd run and the value is only 1.106. Figure 4 depicts similar trends when FRP of TOPSIS is employed. Figure 5 shows the laydown mean of SCI for the 10th run of RP and 3rd run of FRP. It is quite evident that the mean laydown SCI varies widely from 110.463, which is the overall average of SCI for 1200 bales, in case of the former. However, the 3rd run of FRP of SCI, which accounts for the maximum laydown range of SCI, shows very little deviation of laydown mean of SCI from the population mean.

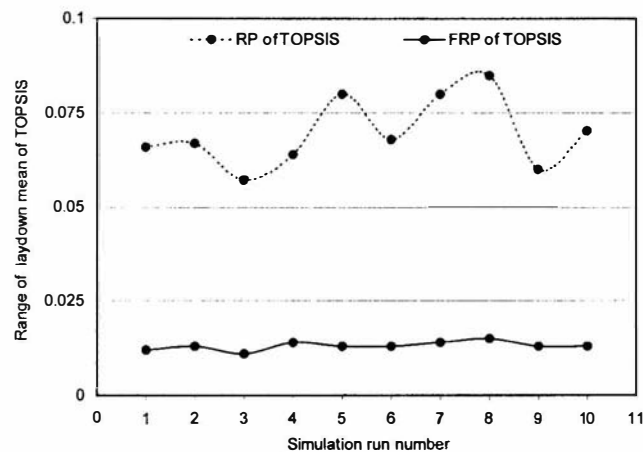


Fig. 4—Range of laydown mean of TOPSIS in different runs

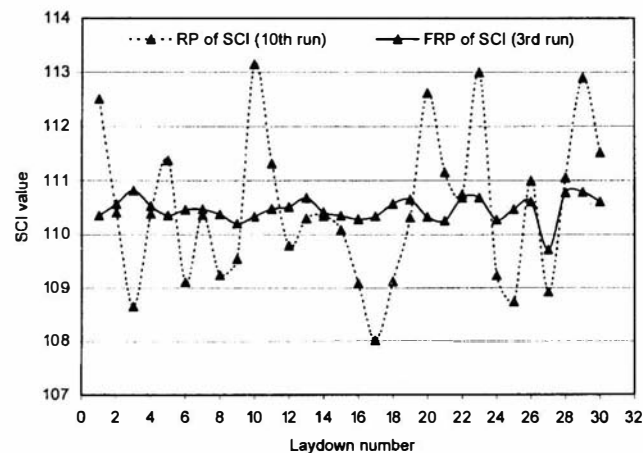


Fig. 5—Comparison of laydown mean of SCI for RP and FRP

4.2 Improvement in the Between Laydown Variance

The between laydown variances of fibre properties are shown in Table 5. It is observed that between laydown variances are rather high when the bales are picked with RP from the population. Both the FRP algorithms, namely SCI and TOPSIS, reduce the between laydown variances of fibre properties. For bundle tenacity and UHML, the FRP of SCI seems to have some edge over the FRP of TOPSIS. SCI grouping reduces the between laydown variances of bundle tenacity and UHML by 24.17% (from 0.0211 to 0.0160) and 40.56% (from 0.0143 to 0.0085) respectively. On the other hand, TOPSIS grouping reduces the between laydown variances of bundle tenacity and UHML by 18.01% and 34.96% respectively. The between laydown variance of UHML for 10 simulation runs of different algorithms is also depicted in Fig. 6. It is observed that FRP methods (shown by solid lines) produce lower between laydown variances of UHML than the RP methods (shown by broken lines). However, the FRP of TOPSIS completely outperforms the FRP of SCI when the between laydown variability of cotton micronaire is considered (Fig. 7). Table 5 shows that

Table 5—Comparison of between laydown variances

Bale picking algorithm	Fibre property			
	Tenacity	UHML	Micronaire	SCI/TOPSIS
RP of SCI	0.0205	0.0127	0.0036	1.2425
RP of TOPSIS	0.0217	0.0159	0.0028	0.000292
RP average	0.0211	0.0143	0.0032	1.2425/ 0.000292
FRP of SCI	0.0160 (24.17)	0.0085 (40.56)	0.0021 (34.38)	0.0488 (96.07)
FRP of TOPSIS	0.0173 (18.01)	0.0093 (34.96)	0.0007 (78.13)	0.000011 (96.23)

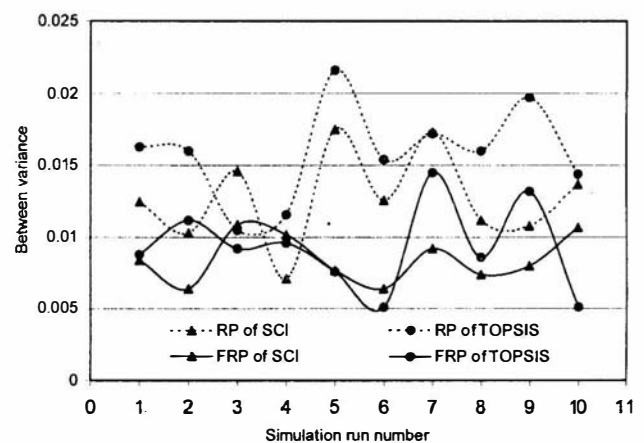


Fig. 6—Comparison of between laydown variance of UHML

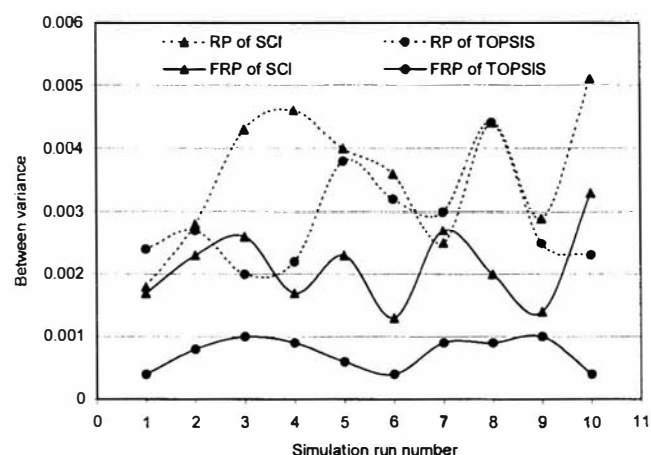


Fig. 7—Comparison of between laydown variance of micronaire

in RP the mean variance of micronaire is 0.0032, which reduces by 34.38% and 78.13%, when the bales picked by FRP of SCI and FRP of TOPSIS respectively. Table 5 also reveals that the between laydown variance of micronaire is three times higher in case of FRP of SCI as compared to that in case of FRP of TOPSIS. Figure 7 clearly depicts that the FRP of TOPSIS is by far the best method with respect to the control of micronaire variance. This finding strengthens the idea that TOPSIS can rein in the variability of cotton micronaire more effectively than the SCI.

It can be inferred from the ongoing discussion that the FRP algorithm is capable to reduce the between laydown variability of fibre properties and thereby pave the way for quality consistency. The efficacy of FRP of SCI to reduce the between laydown variances of micronaire is lower than that of FRP of TOPSIS. Therefore, while employing the FRP of SCI algorithm, the bales can be categorized based on their SCI and micronaire values. This is also recommended by the Zellweger Uster.¹⁰ However, the proposed TOPSIS algorithm provides the desired control over the variability of cotton micronaire without losing much control over the variability of bundle tenacity and UHML.

5 Conclusions

It is demonstrated that the frequency relative bale picking algorithms ensure better control of range of laydown mean and between laydown variances of fibre properties. The TOPSIS method of MCDM is an efficient way of cotton fibre grading, categorizing and laydown. It exerts better control over the variability of micronaire as compared to the established SCI method. At the same time, TOPSIS method also ensure reasonable control over the variability of fibre bundle tenacity and UHML. Therefore, the proposed TOPSIS method can be used in the spinning industries to determine the overall quality of cotton fibre and laydown formation.

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