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MULTI-CRITERIA DECISION MAKING APPROACH USING HYBRID AHP-TOPSIS METHODOLOGY FOR RANKING AND SELECTION OF HANDLOOM FABRICS FOR SUMMER CLOTHING

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Abstract

Amid several alternatives, ranking and selection of a textile fabric for a specific end-use requirement is not a simple task. Because, this situation involves consideration of multiple (of course, finite number of) criteria simultaneously while ranking the fabrics and thereby selecting the best alternative/option. This is a typical situation where multiple criteria decision making (MCDM) technique comes into play. A sincere effort has been made in this paper to devise an index of handloom fabric quality, which should be a benchmark for selecting the handloom fabrics for summer clothing. A new methodology of MCDM technique namely, Analytic Hierarchy Process (AHP) – Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS) hybrid approach has been employed here with a view to ranking 25 handloom cotton plain fabrics and thereby selecting the best alternative in terms of their quality value considering their

Keywords:
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suitability for summer clothing. Three important comfort attributes namely drape coefficient, air permeability and thermal resistance were considered and their relative importance or weights were determined by the formation of a typical pair-wise comparison matrix. Handloom fabrics were ranked according to their relative closeness with respect to the best and worst possible alternatives.

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1. Introduction

Ranking and selection of a textile fabric for a specific end-use requirement like for the purpose of summer clothing is not a simple task. Because, this is a situation which involves consideration of multiple criteria simultaneously while ranking the fabrics and thereby selecting the best one. Under this circumstance, multiple criteria decision making (MCDM) techniques seem to be the most befitting as they can elicit the best alternative based on several quality criteria. In MCDM, commensurate weights can be assigned to different fabric properties exploiting the experience of the textile technologists. MCDM deals with the selection of optimal alternatives according to their preferential rank from all feasible alternatives under the presence of multiple (finite number of) decision criteria. Many exponents of MCDM are available which have enjoyed a wide acceptance in the academic area and many real-world applications. Weighted sum model (WSM), Weighted product model (WPM), the Analytic hierarchy process (AHP), Revised analytic hierarchy process (RAHP), Technique for order preference by similarity to ideal solutions (TOPSIS), and Elimination and choice translating reality (ELECTRE) are among the most popular ones. Each of these methods has its own characteristics and background logic, as well as merits and demerits. User has to choose the suitable method according to complexity of the problems. So, it is very difficult to comment which one is the best MCDM method.

2. General Overview of MCDM Approach

Multi-criteria decision making (MCDM) is a very popular discipline of Operations Research (OR), having relatively short history of about 40 years. Its development has accelerated with the rapid development of computer technology. Computer programming has helped handle huge data related to criteria, sub-criteria, and alternatives, their systematic analysis to tackle MCDM problems which are complex in nature. This has made MCDM extremely important and useful tools in solving business decision making problems.

Although MCDM methods may be widely diverse in nature, they still have following common features:

- Determination of relevant criteria and alternatives of the decision problem.
- Assigning/attaching numerical weights to the relative importance of criteria w.r.t. the objective or goal of the problem and to the alternative scores w.r.t. each of these criteria.
- Processing numerical values to determine the overall quality/priority value, and thereby ranking of alternatives.

Amongst the various exponents of MCDM approach, the AHP is one of the latest and most talked about method which can efficiently handle the tangible as well as intangible attributes. In AHP, the number of pair-wise comparison matrices in a decision problem having M alternatives and N criteria is expressed by the following equation:

$$\frac{N(N-1)}{2} + N.\frac{M(M-1)}{2}$$

which may be practically unmanageable in situations where a large number of decision criteria and alternatives are involved.

TOPSIS, on the contrary, is more efficient in handling the tangible attributes and there is no limit in terms of number of decision criteria or alternatives. Hence, A new technique of MCDM namely, AHP–TOPSIS hybrid method/approach has been employed in this paper for ranking 25 handloom cotton plain fabrics and thereby selecting the best alternative in terms of their quality value considering their suitability for summer clothing.

3. AHP-TOPSIS Hybrid Methodology

The AHP was invented by T.L. Saaty [1-6], which is based on the formation of pair-wise comparison matrix to extract relative weights of criteria and alternative scores. The TOPSIS was developed by Hwang and Yoon [7]. The basic philosophy of TOPSIS is that the selected alternative should have the shortest distance, in a geometrical sense, from the positive ideal solution and longest distance from the negative ideal solution or worst solution. In the case of AHP-TOPSIS hybrid approach, on the other hand, the pair-wise comparison method of AHP is amalgamated with the other steps of TOPSIS. The fundamental steps involved in the AHP-TOPSIS approach [8] are explained as follows:

Step 1:

In this step, the relevant goal/objective, decision criteria and alternatives of the problem are identified.

Step 2

In this step, a decision matrix of criteria and alternatives are produced based on the information available regarding the concerned problem. If number of alternatives is M and number of criteria is N, then the resultant decision matrix having order of M x N can be represented as follows:

$$\mathrm{D}_{\mathrm{M}\times\mathrm{N}} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1N} \\ a_{21} & a_{22} & \cdots & a_{2N} \\ \cdots & \cdots & \cdots & \cdots \\ a_{M1} & a_{M2} & \cdots & a_{MN} \end{bmatrix}$$

where the element a_{ij} represents the actual value of i^{th} alternative in terms of j^{th} decision criteria.

Table 1. The fundamental relational scale for pairwise comparisons proposed by Saaty

Intensity of importance	**Definition**	**Explanation**
1	Equal importance	Two activities contribute equally to the objective.
3	Moderate importance	Experience and judgement slightly favour one activity over another.
5	Essential or strong importance	Experience and judgement strongly favour one activity over another.
7	Very strong importance	An activity is very strongly favoured and its dominance is demonstrated.
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 judgement	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 decision matrix is converted to a normalized decision matrix so that the scores obtained in different scales become comparable. An element $r_{ij}$is calculated as under:

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

Step 4

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 by using a scale of relative importance proposed by Saaty, which is shown in Table I. 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, when$i= j$ and $c_{ji} = \frac{1}{c_{ij}}$. The pair-wise comparison matrix is given by:

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

The relative weight or importance of the ith criteria (W_i) is determined by calculating the geometric mean (GM) of the ith row and then normalizing the geometric means of rows of the above matrix. This can be represented by the following relatons.

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

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

$$C_2 = [W_1 \quad W_2 \quad \dots \quad W_N]^T$$

The principal Eigen vector (λ_{max}) of the original pairwise comparison matrix (C_1) is calculated from the average of matrix C_4. To check the consistency in pairwise comparison, consistency index (*CI*) and consistency ratio (*CR*) are calculated from the following equations.

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

where *RCI* is random consistency index and its value is given in could be obtained from Table II. If the value of *CR* is 0.1 or less then the judgement is considered to be consistent and hence acceptable. Otherwise, the decision-maker has to reconsider the entries of the pair-wise comparison matrix.

Table 2. RCI values for different numbers of attributes (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

Step 5

The weighted normalized matrix is obtained by multiplying each column of the normalized decision matrix *R* by the associated criteria weight corresponding to that column. Hence an element v_{ij} of weighted normalized matrix *V* is represented as follows:

$$v_{ij} = W_j . . r_{ij}$$

Step 6

This step produces the positive ideal solution (A^*) and negative ideal solution (A^-) in the following manner.

$$A^* = \{(\max v_{ij} / j \in J), (\min v_{ij} / j \in J') \; for \; i = 1,2,3, \dots \dots M\} = \{v_1^*, v_2^*, \dots \dots \; v_N^*\}$$

$$A^- = \{(\min v_{ij} / j \in J), (\max v_{ij} / j \in J') \; for \; i = 1,2,3, \dots \dots M\} = \{v_1^-, v_2^-, \dots \dots \; v_N^-\}$$

$$\text{where } J = \{j = 1,2,3, \dots \dots N / j \text{ associated with benefit or positive criteria}\}$$

and $J' = \{j = 1,2,3, \ldots\ldots N/j \text{ associated with cost or negative criteria}\}$

The decision maker wants to have the maximum value among the alternatives for the benefit criteria. Hence, A^* indicates the positive ideal solution. Similarly, A^- indicates the negative ideal solution.

Step 7

The N dimensional Euclidean distance method is applied in this step, as shown below, to measure the separation distances of each alternative from the positive and negative ideal solution.

$$S_i^* = \left\{ \sum_{j=1}^{N} (V_{ij} - V_j^*)^2 \right\}^{0.5}, \quad i = 1,2, \ldots\ldots, M$$

and

$$S_i^- = \left\{ \sum_{j=1}^{N} (V_{ij} - V_j^-)^2 \right\}^{0.5}, \quad i = 1,2, \ldots\ldots, M$$

where S_i^* and S_i^- are the separation distances of alternative i from the positive ideal solution and negative ideal solution, respectively.

Step 8

In this step, the relative closeness (C_i^*) of each alternative with respect to the positive ideal solution is determined using the following equation. The value of C_i^* lies within the range from 0 to 1.

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

Step 9

All the alternatives are now arranged in a descending order according to the value of C_i^*. The alternative at the top of the list is the most preferred one and vice versa.

4. Materials and Methods

4.1 Data Collection and Analysis

The test results include three important attributes namely drape coefficient, air permeability and thermal resistance of 25 handloom cotton fabrics. The summary statistics of handloom fabric properties are shown in Table III. The ranking of 25 handloom fabrics were done according to their quality value by AHP-TOPSIS hybrid method.

Table 3. Summary statistics of handloom fabric properties

Fabric properties	**Minimum**	**Maximum**	**Mean**	**SD**	**CV%**
Air permeability [$cm^3.s^{-1}.cm^{-2}$]	214.23	258.5	234.70	14.69	6.26
Drape coefficient [%]	61.41	80.09	69.68	5.91	8.48
Thermal resistance [$m^2.K.W^{-1}\times10^{-3}$]	7.97	24.65	13.01	2.85	21.91

4.2 Decision Hierarchy of the Problem

The objective of this particular study was to select a handloom fabric from the available 25 alternatives which would serve as the best choice for summer clothing. This objective (to determine the quality value of handloom fabric) was placed at the topmost position (Level 1) of the hierarchy. The decision criteria of the present problem, namely, drape coefficient, air permeability and thermal resistance of the fabrics were placed at the next position in the hierarchy, i.e., Level 2. At the lowest level of the hierarchy (Level 3), there were 25 handloom fabrics to be ranked with respect to the objective of the problem. The schematic diagram of the hierarchical structure of the quality value of the handloom fabric is depicted in Figure 1.

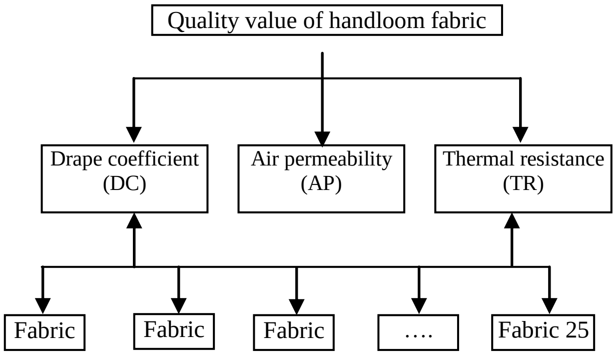

Figure 1. Hierarchical structure of handloom fabric quality

4.3 Determining Criteria Weights

The relative importance or weights of various criteria were determined by constructing a pairwise comparison matrix. The pairwise comparison matrix of three criteria with respect to the overall quality value, in terms of applicability towards summer clothing, is shown in Table IV. Here the elements of Level 2, i.e. decision criteria were arranged into a matrix and judgements were made according to the Saaty's nine-point scale given in Table I.

Table 4. Pairwise comparison matrix of criteria

Criteria	**Drape coefficient**	**Air permeability**	**Thermal resistance**	**Geometric mean (GM)**	**Normalized GM or Relative weights**
Drape	1	1/2	2	1.000	0.2970
Air	2	1	3	1.817	0.5396
Thermal	1/2	1/3	1	0.550	0.1634

It can be inferred from Table IV that air permeability was having moderate predominance over the thermal resistance. However, dominance of air permeability over drape coefficient, and the dominance of drape coefficient over thermal resistance were somewhat between equal and moderate. The relative weights of criteria are shown in the last column of Table IV. It is observed that the air permeability is having the most dominant influence on the quality value of the handloom fabrics with a relative weight of 0.5396. The relative weights of drape coefficient% and the thermal resistance are 0.2970 and 0.1634 respectively. For the measurement of consistency of judgement, the original pair-wise comparison matrix was multiplied by the priority vector or weight vector to get the product as shown below:

$$\begin{bmatrix} 1 & 1/2 & 2 \\ 2 & 1 & 3 \\ 1/2 & 1/3 & 1 \end{bmatrix} * \begin{bmatrix} 0.2970 \\ 0.5396 \\ 0.1634 \end{bmatrix} = \begin{bmatrix} 0.894 \\ 1.624 \\ 0.492 \end{bmatrix}$$

$$\lambda_{max} = \left(\frac{0.894}{0.2970} + \frac{1.624}{0.5396} + \frac{0.492}{0.1634}\right) / 3 = 3.0092$$

Therefore,

$$\text{Consistence Index (C.I.)} = \frac{3.0092-3}{3-1} = 0.0046$$

$$\text{ConsistencyRatio(C.R.)} = \frac{C.I.}{R.C.I.} = \frac{0.0046}{0.58} = 0.0079 < 0.1$$

As the value of C.R. was well below the critical value of 0.10, therefore the pairwise comparison matrix is consistent and acceptable. Since, there was no sub-criterion, the relative weights of the decision criteria represented the corresponding global weights with respect to the objective. Hence, the global weights of the three decision criteria, namely drape coefficient, air permeability, and thermal resistance with respect to the goal were 0.2970, 0.5396, and 0.1634 respectively.

5. Results and Discussion

The weights of the three criteria derived by the pairwise comparison matrix (AHP method) were then used for TOPSIS. The determination of normalized decision matrix and weighted normalized decision matrix were done according to the method described earlier. After the determination of positive ideal solution (*PIS*) and negative ideal solution (NIS) corresponding to each criterion, the separation distances of alternatives from the PIS (S_i*) and that from the NIS (S_i^-) were calculated. The values of separation distances and final closeness index (C_i*) for all the alternatives are depicted in Figure 2.

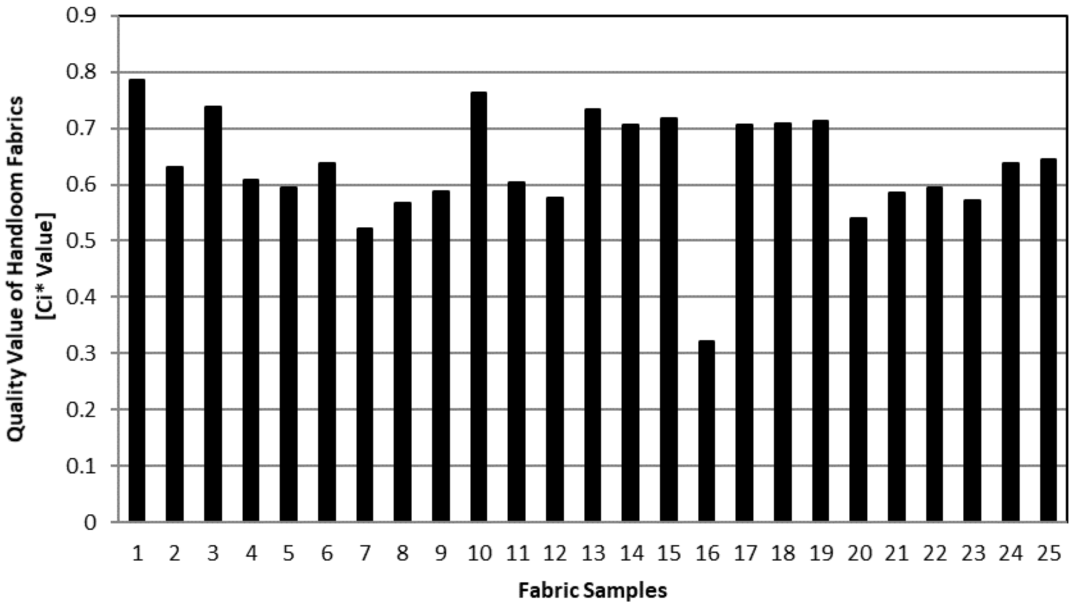

Figure 2. Handloom fabric quality value determined by AHP-TOPSIS

A user-friendly software has been developed using MATLAB platform for the determination of quality value and thereby the ranking of handloom fabrics by AHP-TOPSIS hybrid method.

From Figure 2 it is noted that, sample 1 acquires 1st rank, sample 10 acquires 2nd rank, and sample 3 acquires 3rd rank respectively according to the AHP-TOPSIS hybrid method. The best fabric in this case is sample no. 1 and the worst fabric is sample no. 16 (which ranked 25) with respect to applicability towards summer clothing.

6. Conclusion

A new methodology of MCDM technique has been demonstrated in this paper to evaluate the quality value of handloom cotton fabrics, thereby selecting the best alternative in terms of applicability towards summer clothing. The methodology has been formulated by amalgamating the principles of two popular exponents of MCDM, namely AHP and TOPSIS. All the fabric properties or attributes were given commensurate weights based on their influence on overall objective. The relative as well as global weights of drape coefficient, air permeability, and thermal resistance were found to be 0.2970, 0.5396 and 0.1634 respectively. The final raking of the 25 fabrics was elicited by AHP-TOPSIS hybrid method of MCDM. As the MCDM technique is very flexible, new weight combinations can be developed by modifying the pairwise comparison matrix to cope with the new situation of decision making. The AHP-TOPSIS hybrid methodology exploits the experience of the textile technologists to construct the pairwise comparison matrix, which can be modified very easily in new situation. This approach is a flexible way of decision-making and can be applied in any situation regardless of fabric manufacturing technology. However, 25 handloom fabrics were used here only to demonstrate the analysis, and the results should not be generalized to other fabric datasets.

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