Migration Letters

Volume: 21, No: S13 (2024), pp. 1769-1785

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)

www.migrationletters.com

Evaluation And Grading Of Comfort Characteristics Of Woven Winter Fabrics With Varying Weft Yarns Using Ahp And Promethee Approach

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Abstract

Purpose: The "AHP" and "PROMETHEE" approaches are employed to choose the top-grade woven fabric with the best mechanical, thermal, and sensory comfort characteristics. These techniques permit for a systematic comparison of many fabric choices, ensuring that the final choice joins both performance and comfort standards.

Design/methodology/approach: In the construction of woven fabric, eight yarns were utilized in the study's methodology. The extensive calculation of GSM, thermal resistance, tensile strength, tear strength, pilling level, drapability, smoothness, and wrinkle recovery was carried out in the research methodology.

Findings: The outcomes of the study established that Fabric F7 (micro-polyester/cotton blend) (F7) was declared a best quality fabric from the eight fabric samples. These results indicate that the micro polyester/cotton blend is stable, long-lasting and comfortable and making it best choice for winter clothing. In future, more research work could investigate the long-lasting functioning of the[1] fabrics under several environmental circumstances to realize their useful functions better. Notably, fabric F7 received higher subjective evaluation scores, indicating superior mechanical, thermo-physiological, and sensory comfort.

Originality/value: Fashion brands can create distinctive, superior, and functional fabrics to satisfy their customers. Fashion designers and textile manufacturers may employ the unique characteristics of these yarns to develop textiles that meet the demand of women's winter clothing.

Research implications: Quality is a primary concern for companies attempting to meet the ever-evolving needs of their customers. Textile producers use physical and comfort-related qualities to create innovative fabrics that give them an advantage in the fashion industry and to enhance their brand image.

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Keywords: *Comfort, MCDM, Fashion Industry, Brand Image, Winter Apparel, Customer Satisfaction, Textiles Manufacturers, Fashion Designers.*

1. Introduction

The complexity of purchasing decisions has grown nowadays, drawing researchers' attention once more to particular concepts. The customer no longer needs to choose the product with the lowest price; instead, he prioritizes the product's quality and personal satisfaction. According to earlier research by Beneke et al., (2013), consumers' willingness to buy products is significantly and favorably impacted by both product quality and price because the item they purchase offers the value they desire, particularly comfort. Comfort in clothing may be a key factor for the average consumer in modern times. Fabric manufacturers also aim to create a perfect, visually appealing fabric that will attract their customers.
Comfort is a fundamental attribute when evaluating textile products, and four components of comfort have a crucial impact on customer satisfaction (Figure 1). Comfortable apparel enhances a wearer's output and competence in addition to their general well-being, and only fabrics that put comfort first can thrive in the apparel industry (Classen, 2018). Comfort is considered a multifaceted and intricate phenomenon (Song, 2011). When choosing clothes, consumers now give much thought to comfort in addition to other crucial elements like style, quality, cost, and more. This increased focus on comfort has led to a demand for innovative materials and designs that enhance the wearer's experience. As a result, manufacturers are investing in research and progress to create fabrics that not only look good but also provide superior comfort and functionality. To satisfy consumer demands, clothing must feel good to wear in addition to being well-made and attractive (Matusiak, 2006). Fashion incorporates the latest trends and styles, which can significantly influence psychological comfort. In various regions of Pakistan, particularly the northern ones and those with continental climates, like Azad Jammu Kashmir and Khyber Pakhtunkhwa (KP), temperatures frequently fall below freezing for several months of the year (Mishra, 2007). In general, woven materials are produced for a variety of end uses, each with different functional needs (Jahan, 2017).

To satisfy the demands of both national and international quality-conscious consumers, the weaving industry continues to strive to increase production efficiency while maintaining the quality of woven fabrics.

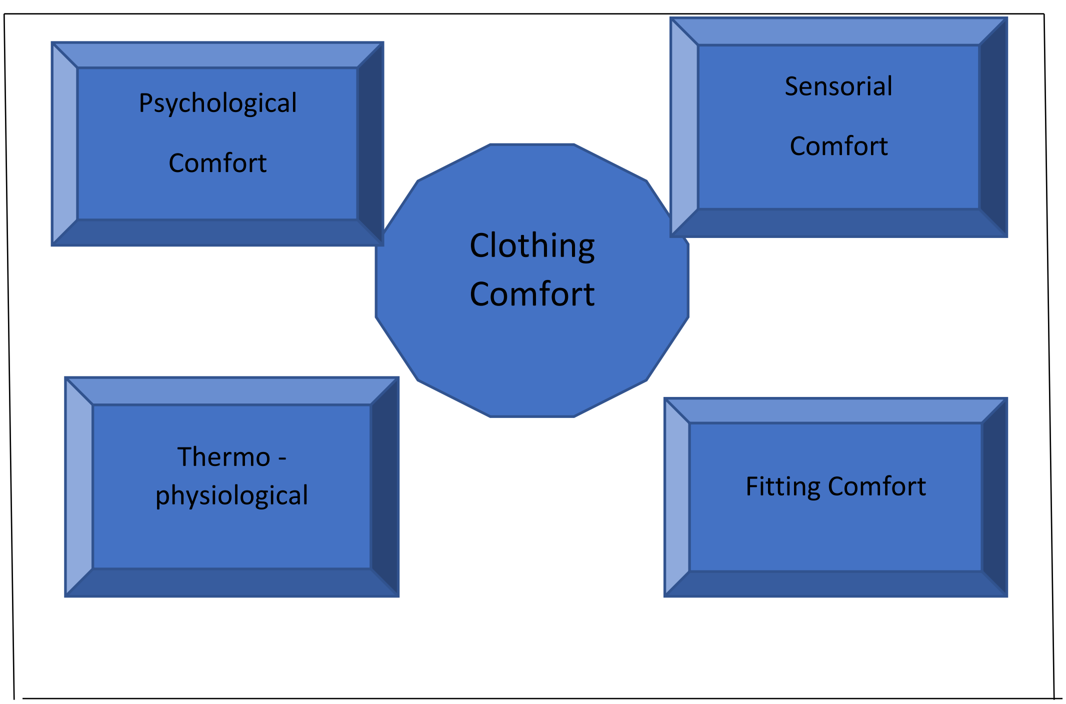

Figure1: Components of Clothing Comfort

The characteristics of fibers, yarns, and fabrics are the main factors that affect the capacity of textile material to regulate heat and moisture (Bhatia & Malhotra, 2016). However, Ucar and Yilmaz (2004) noted the thermal features of rib knitted materials and found that the fabric's density and the number of ribs meaningfully disturb thermal features. These outcomes focus not only on the implication and standing of fabric composition but also on the structural pattern of fabrics in optimizing comfort and functionality. Further research could investigate how different knitting structures affect moisture management and thermal insulation in many environmental circumstances. Such inquiries would provide valuable insights for industries looking to increase the functionality of sportswear and outdoor clothing. By understanding the relationship between knitting methods and fabric qualities, manufacturers could develop advanced solutions tailored to specific customer needs and climate challenges. Fabric's constituent materials such as fiber type, yarn parameters, fabric build-up, and finishing applications, are what largely determine their sensory comfort (Özdemir, 2017). According to a previous research, touch and sight play an equal part in how people assess a product and decide whether to buy it (Jansson-Boyd, 2011). Xue et al. (2016) investigated the relationship between haptic and visual assessments of tactile features, and they concluded that most fabric tactile qualities can be observed without physical interaction.

Many researchers have stated that the consequences of different elements on the tactile properties of knitted and woven materials, including fiber type, blend ratios, fiber cross-sections, finishing treatments, and fabric structure (Bishop, 1996; Kumpikaitė & Milašius, 2003; Du & Yu, 2007; Demiryürek & Uysaltürk, 2013). Kay et al., (2024) concluded a detailed investigation of previous studies on the relationship between fabrics and sensorial experiences in the worldwide. In designing a better adaptive and sensorial clothing, a thorough and relevant review of literature emphasized the need to consider fabric preferences, clothing functionality, aesthetics, and affordability. According to the evidence, the best clothing patterns should integrate seamless, soft cloths with few surface labels, encourage public communication and practical engagement, and be reasonable for everyone. Designers can deliver clothing that increases comfort, usefulness, and general well-being by realizing the relation between fabrics and sensorial practices.

Different approaches and tools exist in Multi-Criteria Decision Making to deal with the choices problem, such as Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), Analytic Network Process (ANP), Multi-Attribute Utility Theory (MAUT), Technique Order Preference by Similarity to Ideal Solution (TOPSIS), Analytic Hierarchy Process (AHP), Preference Selection Index (PSI), Elimination and Choice Expressing Reality (ELECTRE), and Vlse Kriterijumska Optimizacija Kompromisno Resenje (VIKOR).

In 1970, Thomas Saaty established the AHP technique (Saaty, 2008). The current study employed the AHP approach in decision-making to rank various criteria and select the best options. The priority scale is established and depends on professional judgment (Ozdagoglu & Ozdagoglue, 2007). PROMETHEE technique is a straightforward computation outranking technique that takes into account every alternative in a pairwise comparison. Brans generated it (Brans & Mareschal, 2005). Chakraborty and Bandhopadyey (2017) utilized the Promethee-GAIA technique to rank the collection of 17 cotton fiber kinds according to 13 criteria. To examine the ratio of component fibers in blends, researchers used the PROMETHEE II and GAIA models to assess cotton fibers in comparison to chosen alternatives. Chakraborty et al., (2018) established that the comparative weights of the several fiber features did not significantly affect the ratio of the blend. Due to their strength, flexibility (the ability to bend, shear, and twist), permeability, and drapeability, textile fabrics have been used for a long time for the profit and assistance. These particular features must exist in fabrics to offer suitable comfort, style, and protection (Hu & Kumar, 2018). Developments in textile expertise are continuously improving these qualities, resulting in advanced materials that not only accomplish aesthetic demands but also improve functionality. As researchers investigate sustainable options, the overall fashion business is becoming more devoted to the fibers and yarns that are more eco-friendly. This shift towards sustainability reflects an increasing awareness of the environmental impacts associated with the fashion industry. So, designers and manufacturers should select those materials that could reduce ecological footprints. Therefore, the incorporation of recycled and organic fibers into conventional fashion is gaining grip, offering customers wise choices that support their values.

Today, for the survival of any business, it is necessary to attract customers to their brand in the long term, because satisfied customers will use it for a long time. Thus, evaluating textile product quality is crucial to meeting customer needs. Selecting the best fabric from a range of options, especially when faced with conflicting criteria, is a contentious issue in the apparel industry when applying the “Multi-Criteria Decision-Making Method”. The integration of the visual PROMETHEE approach with the “Analytical Hierarchy Process” (AHP) results in a comprehensive framework of ranking and selecting fabrics based on various criteria. The present study will combine AHP and PROMETHEE as a comprehensive method for choosing and ranking fabrics for winter apparel for women based on a range of physical, thermo-physiological, and comfort features.

1.1 Purpose

Present study explores the quality of woven yarn fabrics for ladies’, focusing on their mechanical, thermal, and sensory comfort qualities for winter season.

1.2 Research Questions

The following questions were prepared for the current study:

RQ1. Do the yarn fabrics comprise good mechanical, thermal, and sensorial comfort properties?

RQ2.Which yarn blend fabric will show the best features for winter wear?

RQ3. How do the fabric manufacturers meet the requirements that affect the overall performance of winter fabrics for female consumers?

2. Material and Methods

A quantitative research methodology was used to examine the physical and comfort attributes of the sample fabrics.

2.1 Material

For the current study, synthetic yarns (100%) were sourced from various Chinese companies, including polypropylene, poly viscose, viscose, acrylic, polyester, hollow polyester, and micro polyester. At the same time, cotton (100%) yarn was purchased from the local market of Faisalabad (Pakistan). Eight criteria such as fabric weight (GSM)(C1), thermal resistance (C2), pilling level (C3), softness (C4), drape (C5), wrinkle recovery (C6), tensile strength (C7), and tear strength (C8) depicts the hierarchy of decisions for selecting the best fabric (Fig 2).

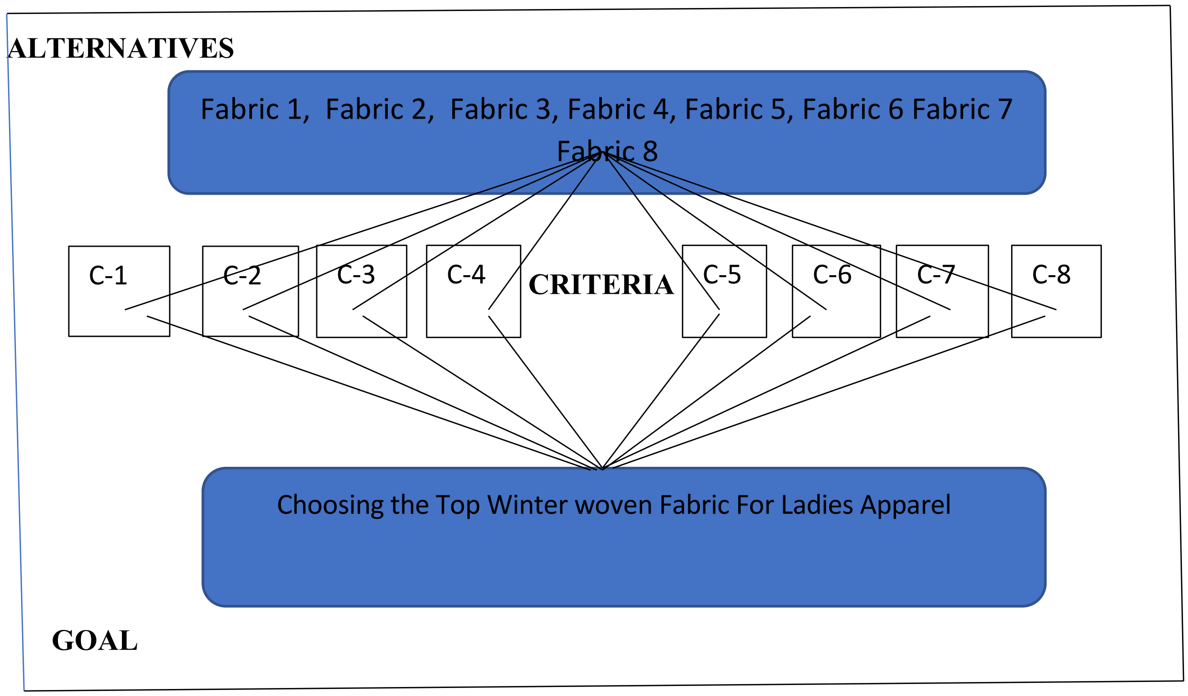

Figure 2: A Hierarchy of Decisions for Choosing the Top Fabric

3.2: Testing

The current study was completed using the following 3-staged methodology (Figure 3).

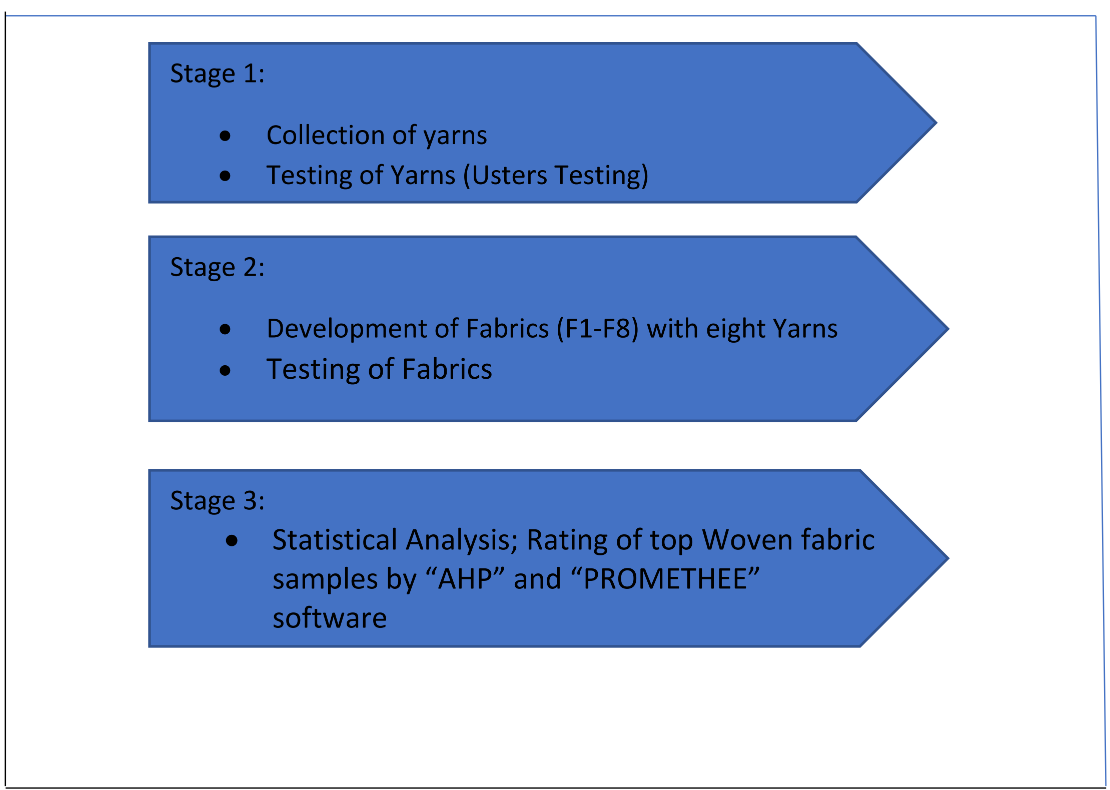

Figure 3: 3-Staged Methodology

Stage I
Uster testing was carried out to verify the yarn characteristics of the collected samples, and then fabrics were developed.

- **Stage II**

Eight yarn samples were used to construct the fabrics (F1-F8) in the 2nd stage of the study; Table 1 provides a detailed specification of each sample. All of the fabrics were manufactured on the sample loom with a uniform 19-cover factor (CF). In the weaving operation, cotton yarn was used as a constant in warp yarns for all fabrics, while the weft yarns varied accordingly. These sample fabrics were produced at the "National Textile Research Center" (NTRC), National Textile University, Faisalabad (Pakistan). Eight criteria were employed to assess the comfort features of sample fabrics such as, cloth weight (GSM), drape, softness, pilling, tensile strength, tear resistance, and wrinkle recovery.

Table 1: Description of Woven- fabric Samples

	Sample-No	**Weave-Design**	**Weft -yarn**	**Warp -Yarns**	**Count –(Ne)**	**Cover -Factor (CF)**
Woven Fabric Samples	1.	1x1	Poly propylene	Cotton	30	19
	2.	1x1	Poly viscose	Cotton	30	19
	3.	1x1	Viscose	Cotton	30	19
	4.	1x1	Acrylic	Cotton	30	19
	5.	1x1	Cotton	Cotton	30	19
	6.	1x1	Polyester	Cotton	30	19
	7.	1x1	Hollow polyester	Cotton	30	19
	8.	1x1	Micro polyester	Cotton	30	19

The study employed several testing tools to measure the mechanical, thermos-physiological, and sensory comfort characteristics. These tools include the Fabric Thickness meter, GSM cutter, Pilling Roaches Martindale tester, Yarn evenness and hairiness (USTERS-5) tester, Fabric Tensile Strength (Universal Strength) tester, Fabric Hand Tester (Phabrometer), and Thermal resistance (PERMETEST) tester. Many tests were carried out to evaluate the yarns and sample fabrics, including Count of Yarn (ISO 2060-1994), Yarn Twist (ISO 17202:2002), Fabric Weight (ISO 3801 1977), Yarn Hairiness and Evenness (ASTM D 1425-14), Pilling (ISO 12945-2, ASTM D4970), Thermal Resistance (ISO Standard 11092), Strength and

Elongation of Yarn (ISO 2062:2009), Hand Value of the Fabric (AATCC, ISO 15380), and Tear Strength (ISO 13937-1:2000, Elmendorf Method). Tensile Strength (ISO 13934 -1: 2014).

2.3 Analysis

The “AHP” and “PROMETHEE II” techniques were used to investigate the experimental records. These methods were specially practiced to grade winter woven fabrics using multi-criteria weights to identify the top-grade fabric that holds maximum physical, thermos-physiological, and sensorial features.

3. Results and Discussion

The study used eight different sample yarns, including polypropylene, poly-viscose, viscose, acrylics, polyester, micro polyester, hollow polyester, and cotton for constructing eight fabric samples.

Table 2 depicts that the Uster Tester was employed to measure yarn evenness (CVm), neps (+200%), hairiness, thick spots (+50%), and thin spots (-50%). The sum of the thick and thin areas and the neps was used to determine the overall number of yarn flaws. In quality control, process optimization, and initial quality calculation, strand evenness values are essential, especially when linked with yarn strength calculations (Hossain and Samanta, 2019). Micro polyester yarns had a lower evenness value (10.62), which is generally preferred. Higher evenness values (17.37) for acrylic yarns indicated less-than-ideal yarn manufacturing, reduced yarn strength, and a less appealing material. As the number of fibers in the yarn cross-section varies depending on the fiber characteristics, this could be the primary cause of the yarn's unevenness (Pegram, 2000).

Irregular yarns and weaving techniques can cause irregularities and un evenness in the woven material. Both periodic and non-periodical yarn irregularities are known to produce the moiré impression, cloud effects, and stripe effects in the flat textile. It is possible to predict the appearance of flat textiles using distinctive practices (a variance-length curve, a spectrogram) and computed values of yarn mass irregularity. Surface unevenness in woven textiles is measured based on appearance, usually subjectively rather than physically. The yarn quality level can be calculated using USTER® STATISTICS (Jiraskova and Mouckova, 2013). Semnani et al., (2005, 2006) presented a process for ranking the appearance of different kinds of yarn using artificial neural networks and image analysis. Beran et al., (2009) offered a novel process for assessing the surface of yarn as an autonomous creation. However, Liang et al., (2012) demonstrated how to evaluate and intelligently characterize the appearance of yarn surfaces using saliency map analysis, fuzzy neural networks, and wavelet transform.

Table 2: Yarns Specification

Sample No	**Count**	**Poly-viscose**	**Viscose**	**Acrylics**	**Cotton**	**Hollow-polyester**	**Micro -Polyester**

Nominal-Count	Nec	19	15	15	15	15	15
Actual-Count	Nec	37.8	29.95	29.26	30.85	29.45	31.36
Twist per Inch, (TPI)	1/in	297.2	21.08	259.4	295.4	27.8	20.42
USTER-Evenness, CVm	%	15.08	12.84	17.37	15.52	12.17	10.62
Thin, (-50 %)	1/km	14.8	1	96.4	12.4	1.2	0.2
Thick, (+50%)	1/km	79.8	21	68.6	147	10.4	1.4
Neps ,(+200%)	1/km	202.6	48.8	94.6	436	16.2	3.8
Total Imperfections, (IPI USTER-Hairiness)	1/km	297.2	70.8	259.4	595.4	27.8	5.4
	-	7.45	5.91	10.72	5.57	6.89	2.6
Hairiness Standard Deviation, (sH)	-	1.97	1.46	3	1.45	1.84	0.56
Single End Strength, (5 m/min)	CN	380.6	307.9	305.2	292.3	601.5	520.8
Strength variation CVb, (5mm/min)	%	11.24	8.33	11.78	11.36	9.63	31.56
Single End Elongation, (5 m/min)	%	8.71	14.52	14.87	3.68	10.05	11.09

Coefficient of Variation Elongation, 5m/min	%	7.69	7.95	11.29	10.54	7.14	24.76
Single End Tenacity, (5 m/min)	CN/tex	23.21	15.64	15.51	14.85	30.57	26.46
Coefficient of Variation Tenacity, (5m/min)	%	11.24	8.33	11.78	11.36	9.63	31.56

3.1: Development and Testing of Fabrics

After yarn testing, eight woven fabric samples coded F1–F8 were manufactured in a plain (1x1) weave structure. All of the fabrics were prepared on the sample loom with a uniform 19-cover factor (CF). In the weaving operation, cotton yarn was used as a constant in warp yarns for all fabrics, while the weft yarns varied accordingly. All fabrics(samples) were manufactured at the National Textile Research Center (NTRC), National Textile University, Faisalabad. The fabrics were made with areal thickness (densities) (GSM) ranging from 105 - 131 g/m², preparing them for the winter season. Table 3 presents the details of the fabrics (samples). To keep the PPI below the EPI, the weaving parameters were carefully changed. Higher ends per inch (EPI) and lower picks per inch (PPI) were used to control manufacturing costs and increase contraction in the width of the fabric during the weaving process. Woven materials were tested for their mechanical, sensorial, and thermal properties.

Table 3: Details of the Woven-Fabric Samples

Sample No	**Weft-Yarn**	**Warp-Yarn**	**Weave- Design**	**Count**	**Cover -Factor**	**Warp- Ne**	**Weft -Ne**	**PPI**	**EPI**	**Thermal -Resistance**	**Softness**	**Pilling- Level**	**Drape**	**Wrinkle-Recovery**	**Weight of Fabric (GSM)**	**Tensile Strength**	**Tear Strength**
1.	Polypropylene	Cotton	1x1	30	19	30.85	35.43	40	60	0.1	80.89	4.5	7.58	75.2	105	742	18.4
2.	Poly Viscose	Cotton	1x1	30	19	30.85	37.8	40	60	0.112	83.5	1	6.54	82.18	112	574.5	24.15

3.	Viscose	Cotton	1x1	30	19	30.85	29.95	40	60	0.15	83.93	0	6.26	80.32	129	608	18.3
4.	Acrylics	Cotton	1x1	30	19	30.85	29.26	40	60	0.17	82.12	1.2	6.05	88.85	131	673.5	15.15
5.	Cotton	Cotton	1x1	30	19	30.85	30.85	40	60	0.128	82.1	2	5.98	80.45	115	636.5	16.3
6.	Polyester	Cotton	1x1	30	19	30.85	30.43	40	60	0.123	83.46	4	5.79	87.74	112	753.5	26.95
7.	Hollow Polyester	Cotton	1x1	30	19	30.85	29.45	40	60	0.107	82.87	1.2	5.54	81.36	121	861	26.65
8.	Micro Polyester	Cotton	1x1	30	19	30.85	31.76	40	60	0.14	82.7	2.3	5.46	78.6	116	819	24.5

3.2: Collection and Ranking of Top Woven Fabric via AHP- PROMETHEE AHP – PROMETHEE

Table 4: Pairwise Contrast of Rating Scales

Scale	Grade of Importance	Description
1.	Having-Equal Significance	2 criteria for the goal are likewise significance.

3.	Having-Moderate Significance	The significance of one criterion is marginally greater than other.
5.	Having -Strong Significance	1 criterion is significance than other.
7.	Having Very Strong Significance	1 criterion is more significance than the other.
9.	Having-Enormously Significance	1 criterion has enormously significance than another

2,4,6,8 is applied to describe midway standards

Table 4 presents a group of 20 young ladies, aged 20-40, who were made to assign criteria weights utilizing the “Analytic Hierarchy Process” (AHP) technique. Many authors described the basic concept and approach of AHP (Chakraborty & Bandhopadyay, 2017; Balalil, et al., 2014).

Table 5: A Matrix of Pairwise Comparisons for Weights and Criteria

S. No	Criteria	Fabric- Weight (GSM)	Thermal -Resistance	Pilling -Level	Softness	Drape	Wrinkle -Recovery	Tensile -Strength	Tear- Strength	Normal-Principle Eigenvector
1.	Fabric-weight (GSM)	1.00	0.3	0.88	0.71	1.67	0.6	0.38	0.8	10.23 %
2.	Thermal-Resistance	3.3	1.00	0.6	1.5	1.21	1.00	0.6	1.8	13.05 %
3.	Pilling-Level	1.14	1.66	1.00	1.00	1.43	0.71	0.5	1.2	14.58 %
4.	Softness	1.4	0.61	1.00	1.00	2.5	1.00	0.37	0.831	11.05 %
5.	Drape	0.6	0.83	0.71	0.4	1.00	0.4	0.66	0.75	9.68 %
6.	Wrinkle-Recovery	1.671	1.00	1.41	1.00	2.5	1.00	1.00	0.83	13.90 %
7.	Tensile-Strength	2.67	1.62	2.2	2.71	1.5	1.00	1.00	0.63	13.73 %
8.	Tear-Strength	1.25	0.57	0.83	1.2	1.33	1.2	1.61	11.00	13.78 %

Additionally, the "normalized Principal Eigenvector" is shown in the right column of Table 5. It is noted that the priority vector's total of all elements is 100% after normalization. The priority vector shows how many criteria are given different weights. The AHP presents the criteria, goal, and alternatives in a family tree-like hierarchical structure.

Table 6: Utilizing the "AHP" computation and the Verification of the criteria, stability intervals, and weights

Criteria- Codes	Fabric -Criteria	Fabric-Weight	Maximum	Minimum	Stability interval	λMax, CI, RI	CR
C1	Fabric- weight (GSM)	0.10	0.14	0.06	0.08		
C2	Thermal- Resistance	0.13	0.18	0.78	-0.6	λMax=8.91	
C3	Pilling-level	0.15	0.24	0.06	0.18		
C4	Softness	0.11	0.17	0.06	0.11	CI=0.13	
C5	Drape	0.1	0.17	0.03	0.14	RI=1.24	
C6	Wrinkle- recovery	0.14	0.26	0.02	0.24		0.10
C7	Tensile- strength	0.14	0.23	0.02	0.21		
C8	Tear -strength	0.14	0.19	0.09	0.1		

Table 6 show the results obtained from the Analytic Hierarchy Process (AHP) calculation. The consistency ratio (CR) value of $0.10 \leq 0.1$ indicates that the subjective judgments of the assessment team are stable and do not require any improvements.

Table 7: Net-Flow Chart for Woven-Fabrics Samples

S. No	Alternatives	Net-outranking flow	Positive-outranking flow	Negative-outranking flow
1.	F-7	0.1715	0.1844	0.0129
2.	F-8	0.1117	0.1645	0.0528
3.	F-5	-0.0297	0.0861	0.1158
4.	F-4	-0.0404	0.1054	0.1458
5.	F-3	-0.0483	0.1050	0.1533

6.	F-6	-0.0516	0.1064	0.1580
7.	F-1	-0.0539	0.1176	0.1715
8.	F-2	-0.0594	0.0713	0.1306

Table 7 displays the outcomes of the PROMETHEE-II evaluation, which assessed the eight woven fabric samples developed from blended yarns using identical weights and criteria as those listed in Tables 5 and 6. The study discovered that the preferences for the fabric samples are ranked. Notably, the most popular choice was fabric sample coded F7, which is a blend of hollow polyester and cotton. F8, which is a blend of micro polyester and cotton, came in second. On the other hand, F2, a poly viscose and cotton blend, was the least popular choice for women's winter clothing. Previous researchers who also examined the characteristics and preferences of different fabric mixes (Majumdar & Singh, 2014; Chakraborty et al., 2017; Iftikhar et al., 2020; Amallynda et al., 2022; Fadara et al., 2023) have found similar results to these. The agreement between the existing results and previous text strengthens the validity for employing the PROMETHEE-II evaluation approach to analyze fabric preferences**.**

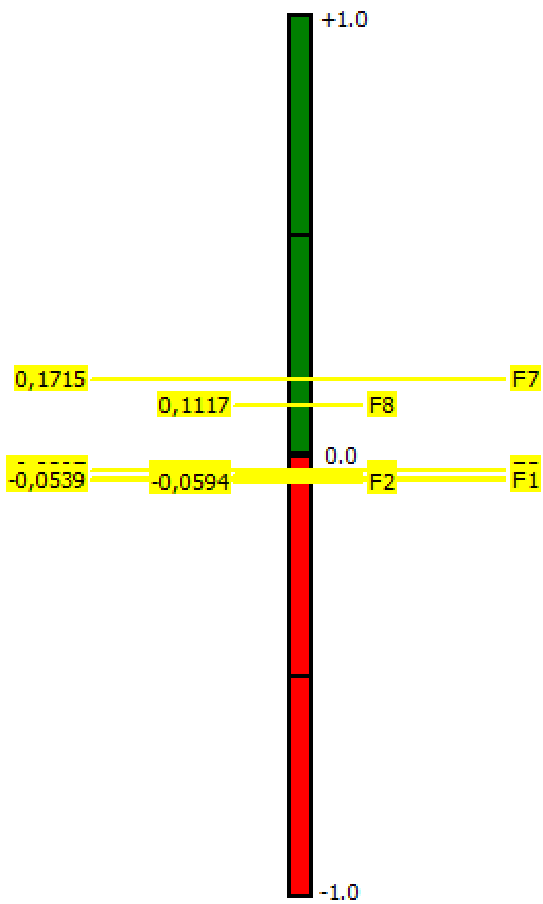

Figure 4: Grades of the 8-Woven Fabric Samples for Women's Winter Clothes

In Figure 4, the relative grading of woven fabrics is graphically expressed using a bipolar scale from -1.0 to 1.0. The two segments of this scale indicate the extent to which each fabric performs better or worse than the others, representing both positive (+ve) and negative (-ve) net outranking flows. The results make it evident which textiles perform the best and worst. However, the highest-grade fabric with a net outranking flow rate of 0.1715 is fabric coded F7 (hollow polyester/cotton), which is composed of 100% hollow polyester in warp yarns and 100% cotton in weft yarns. Based on all of the criteria considered and the overall calculations depicts that, fabric coded F7 outperforms the other fabrics. With a net out-ranking flow rate of 0.1117, fabric coded F8 (a blend of micro polyester and cotton) came in second. Because it offers a nice blend of qualities for this particular use, F7 is the best option for women's winter clothing among blended fabric options. Because of its outstanding performance, this fabric is a good choice for producing cozy, high-quality winter apparel for women.

In comparison to the other fabrics, the F2 poly viscose/cotton blend performs poorly, as evidenced by its lowest net out-ranking flow rate of -0.0594. It is simpler to compare and choose the ideal fabric for a given application thanks to this diagram, which delivers a clear visual depiction of the relative ranks of the fabrics. For fabric suppliers and engineers aiming to produce high-quality, aesthetically pleasing goods for specific applications, such as women's winter clothing, the grading of preferences between fabric samples provides valuable insights. The eight criteria of the woven fabric samples F1–F8 were examined in this study using the PPOMETTHEE method. Fabric F7 demonstrated the best results in terms of the criteria, namely fabric weight (GSM) (C1), tensile strength (C7), tear strength (C8), and softness (4), according to the fabrics' investigation and computations. However, some criteria, like drape (C5), wrinkle recovery (C6), thermal resistance (C2), and pilling level (C3), had unsatisfactory or fair results.

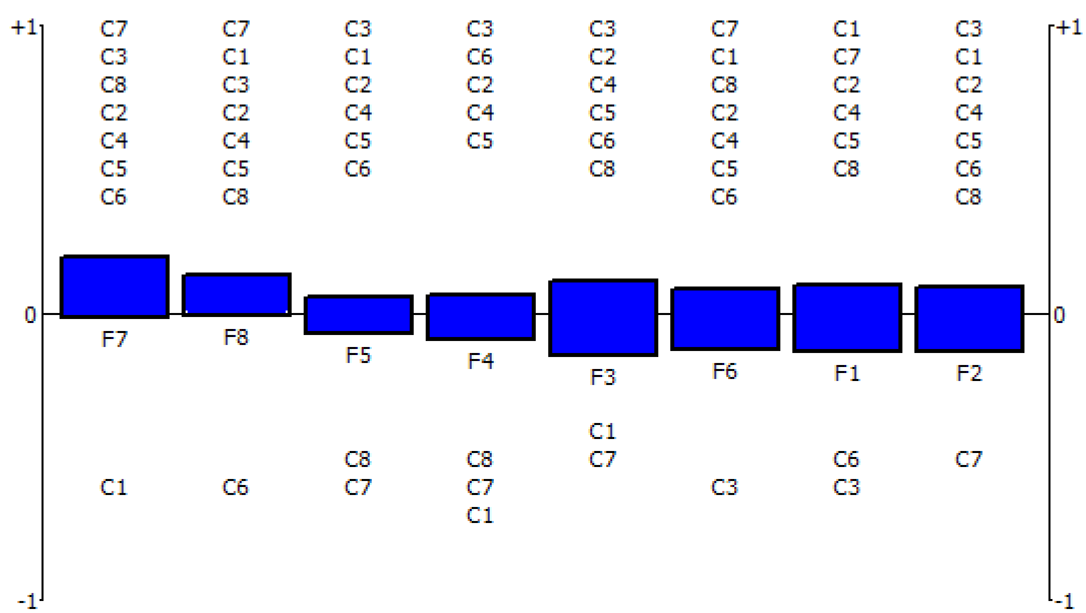

Figure 4: Rainbow of PROMETHEE of Woven-Fabrics for the ladies'

Figure 4 depicts the PROMETHEE rainbow, which ranks alternate woven materials from left to right. The diagram illustrates that F7is the best grade fabric with the upper net outranking flow (0.1715), while F2 has the lowest grade (-0.0539). Criterion 2, 3, 4, 5, 6, 7, and 8, after F8, as seen in the highest vertical bar, highlight the highest positive aspect. The ranking on the far-right confirms F2, indicating a poor grade of fabric.

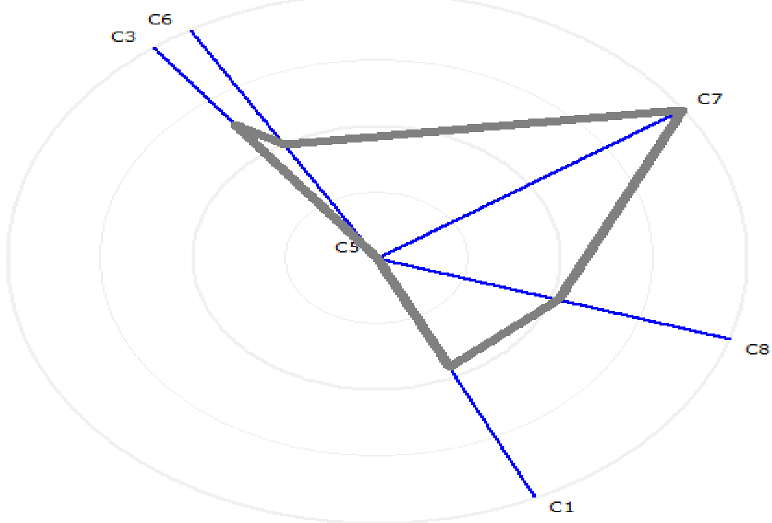

Figure 5: The subsidy criterion of ideal fabric-F7

The GAIA plane, which illustrates the distribution of fabric options and selection criteria, is shown in Figure 5. Vectors denote the eight criteria, while squares signify the alternatives. However, for the criteria, equivalent preferences are expressed by slanted angles in the exact directions, while the criteria that deliver different options are angled in opposite sides (Chakraborty et al., 2017). In Figure 5, for example, the GAIA plane of fabric coded F4 represents C6, C3 (wrinkle recovery, pilling level) coefficients, which are represented in the near axis, and similar alternatives are shown by points that are close to one another. A more discriminating criterion is provided by the GAIA plane's longer criteria axis. The ruling axis is represented with a red vector in the GAIA plane, which is positioned to the option that is most preferred. Furthermore, the specific preferred alternative for that criterion is displayed by other alternatives that are close to it. Given their distance from the midpoint, the GAIA for the fabric F2 indicates that C1 and C8 (fabric weight (GSM) and tear strength) are separate and substantially different from one another. The PROMETHEE technique employs the existing criterion weights to confirm fabrics that align with the decision axis. That is a practical method which could successfully integrates sources of data (qualitative and quantitative) (Tong et al., 2021).

Conclusion

In the current study comfort related properties including mechanical, thermal, and sensory aspects of winter woven apparel for Pakistani women are measured. AHP and PROMETHEE software was utilized that identified that fabric F7 was found the best fabric, made in plain weave having a 19-cover factor. The fabric signified the higher mechanical and comfort characteristics, making it the best choice for ladies' apparel. Moreover, the outcomes of the study also proposed that fabric F7 (micro polyester/cotton blend) is the ideal option during winter, which offers exceptional tensile strength (C7), tear strength, and softness (C4).

Recommendation

The outcomes of the study declared that fabric F7 (micro polyester/cotton blend) was found the superior fabric for ladies' winter apparel. So, in future more research. The study found that the best fabric was produced with a blend of micro polyester/cotton yarns. Consequently, more research can be conducted to study different fiber and yarn blends. Present study utilized only

AHP and PROMETHEE techniques while, other techniques of MCDM can be adopted to choose and grade the fabrics. The outcomes of the research could be confirmed through user or customer trials and practical uses in aggregation with textile industries and fashion brands. So, that could fill the gap found between theoretical assessment and actual customer approval.

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