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Comparison among Two Analytical Methods of Multi-Criteria Decision Making for Appropriate Spinning Condition Selection

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Abstract: This paper makes an attempt to evaluate final ranking of the alternatives proposed by two different approaches of multi-criteria decision making (MCDM) in detecting the suitable spinning process variables for spun yarn intended to be used in knitting process. Performances of three variables in a draw frame were evaluated on the basis of seven quality parameters of the forty eight rotor yarns using technique for order preference by similarity to ideal solutions (TOPSIS) and vlseKriterijumska optimizacija i kompromisno resenje (VIKOR). Both methods are based on an aggregating function illustrating closeness to the ideal. Linear normalization and vector normalization are used in VIKOR and TOPSIS respectively to eliminate the units of criterion function. Difference in normalization technique affected final rankings as they introduced two different alternatives as the best. It means that, selecting appropriate MCDM method to rank feasible alternatives and accepting proposed yarn sample or process condition is related to the economical advantages and efficiency of the spinning and knitting processes.

Key words: Multi-criteria decision making · TOPSIS approach · VIKOR method · Draw frame · Rotor spun yarn · Weft knitted fabric

INTRODUCTION

Yarn production process is accompanied by drafting of staple fibers assemblies from beginning to the end. In a drafting arrangement, break draft, roller setting, production speed and top arm pressure are some important variables that affect drafting quality [1]. From 1950 many researchers have focused on perception of relationship between these parameters and their effects on yarn structure and its properties [2, 3].

Studies show that, relationship between above-mentioned variables and yarn characteristics is very deep and complex [4-6]. Therefore, selecting suitable processing condition among available alternatives is a difficult task and better outcomes about the desired final product properties will be achieved if the priorities of the spinner are taken into account [7].

In recent years, multi-criteria decision making (MCDM) has been employed extensively in various scientific disciplines [8]. Suitable nozzles in a rotor spin-box have been selected by ELECTRE outranking method [7]. Organic fibers have been ranked by MCDM approach [9]. The technological value of the cotton fibers is determined by a hybrid method of MCDM [10]. This method was used to chose cotton fibers and lay-down in a blow-room [11].

MCDM is a branch of operations research (OR). This technique treats with solving problems while a finite number of decision criteria and alternatives are present. TOPSIS and VIKOR are widely used methods of MCDM. Since, there is not published literature that focuses on comparing selection of alternatives using these methods in the field of textile, this study makes an attempt to use them in reaching acceptable solution in order to select the appropriate draw frame parameters that results spun yarn with the best quality parameters to use in weft knitting process and to compare their final rankings.

A Brief Overview of TOPSIS: Multi-criteria decision making is a complex process consists of one managerial level and one engineering level. Such kind of the problem is expressed in decision matrix format.

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$$\begin{array}{cccccc} & C_1 & C_2 & \cdots & Cn \\ A_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ A_2 & x_{21} & x_{22} & \cdots & x_{2n} \\ Am & x_{m1} & x_{m2} & \cdots & x_{mn} \end{array}$$

where; A_1, A_2,.., Am are available alternatives. Decision makers have to choose among these alternatives. C_1, C_2, …, C_n are criteria with which alternative performance are measured, x_{ij} is the rating of alternative Ai with respect to the criterion Cj [12].

Hwang and Yoon (1981) developed TOPSIS for solving a MCDM problem. In this method, the selected alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution [12, 13]. Below steps show the procedure of TOPSIS in details [12].

- Calculating normalized decision matrix (r_{ij} values)

$$r_{ij} = f_{ij} / \sqrt{\sum_{j=1}^{J} f_{ij}^2}, j = 1,....,J \quad i = 1,...n \tag{1}$$

- Calculating weighted normalized decision matrix (υ_{ij} value)

$$\upsilon_{ij} = \omega_i r_{ij}, \quad j = 1,...J, \quad i = 1,...n, \tag{2}$$

where ω_i is the weight of the i^{th} attribute or criterion and $\sum_{i-1}^{n} \omega_i = 1$

- Determining the positive and negative ideal solutions

$$A^+ = \{\upsilon_1^+,.....\upsilon_n^+\} = \{(\max_j \upsilon_{ij} | i \in I),(\min_j \upsilon_{ij} | i \in J)\} \tag{3}$$

$$A^- = \{\upsilon_1^-,.....\upsilon_n^-\} = \{(\min_j \upsilon_{ij} | i \in I),(\max_j \upsilon_{ij} | i \in J)\} \tag{4}$$

In these equations I is associated with benefit criteria and J is associated with cost criteria:

- Calculating separation measure using the n-dimensional Euclidean distance

$$D^+{}_j = \sqrt{\sum_{i=1}^{n} (\upsilon_{ij} - \upsilon_i^+)^2} \quad j = 1,....,J. \tag{5}$$

$$D^-{}_j = \sqrt{\sum_{i=1}^{n} (\upsilon_{ij} - \upsilon_i^-)^2} \quad j = 1,....,J \tag{6}$$

- Calculate the relative closeness to the ideal solution of the alternative A_j with respect to A^+.

$$CC^*{}_j = D_j^- / (D_j^+ + D_j^-), \quad j = 1,...,J. \tag{7}$$

For $D_j^- \geq 0$ and $D_j^+ \geq 0$, $CC^* j \in [0,1]$

- Ranking the preference order.

A Brief Overview of VIKOR: In the engineering studies after generating the alternatives, MCDM methods are used to propose a solution to the decision-maker [14]. Opricovic and Tzeng presented VIKOR method for multi-criteria optimization of complex systems [15, 16]. VIKOR is borrowed from Serbian and means multi-criteria optimization and compromise solution [17]. The compromise ranking-list, the compromise solution and the weight stability intervals for priorities stability of the compromise solution got with the initial weights are determined by VIKOR [14].

Each alternative is assessed according to each criterion function. The compromise ranking could be conducted by comparing the measure of closeness to the ideal solution f^*. The compromise solution f^c is defined as a solution with the shortest distance to the ideal solution. The multi-criteria measure is developed from the L_p-metric used as an aggregating function in a compromise programming technique. Denote alternatives as a_1, a_2,...., a_j. For alternative a_j the rating of the i^{th} aspect shown by f_{ij}, *i.e.* f_{ij} is the measure of the i^{th} criterion function. Following form of the L_p-metric is used to develop the VIKOR.

$$L_{P,j} = \left\{\sum_{i=1}^{n}\left[w_i\left(f_i^* - f_{ij}\right)/\left(f_i^* - f_i^-\right)\right]^p\right\}^{1/p} \quad 1 \leq p \leq \infty \quad j = 1,2,. \tag{8}$$

$L_{1,j}$ (S_j in Equation 9) and $L_{\infty,j}$ (R_j in Equation 10) are employed to formulate ranking value. The solution proposed by $\min_j S_j$ is accompanied by a maximum group utility (majority rule). Beside, the solution achieved by $\min_j R_j$ is with a minimum individual regret of the opponent. F^c is a solution with the shortest distance from the ideal F^*. Compromise means agreement developed by mutual concessions by $\Delta f_1 = f_1^* - f_1$ and $\Delta f_2 = f_2^* - f_2^c$. Ranking alternatives by VIKOR is conducted in five steps.

- Determining the best f_i^* and the worst f_i^- values of all criterion functions by decision makers. If the i^{th} function shows a benefit: $f_i^* = \max_j f_{ij}$ and $f_i^- = \min_j f_{ij}$

- The values of S_j and R_j, $j = 1,2,...,J$ are calculated by the following relations.

$$S_j = \sum_{i=1}^{n} w_i \left(f_i^* - f_{ij}\right)/\left(f_i^* - f_i^-\right) \quad (9)$$

$$R_j = \max_i w_i \left[\left(f_i^* - f_{ij}\right)/\left(f_i^* - f_i^-\right)\right] \quad (10)$$

- The values of Q_j, $j = 1,2,..., J$ are computed.

$$Q_j = V\left(S_J - S_J^*\right)/\left(S_J^- - S_J^*\right) + (1-\upsilon)\left(R_j - R_j^*\right)/\left(R_j^- - R_j^*\right) \quad (11)$$

where; $S^* = \min_j S_j$, $S^- = \max_j S_j$, $R^* = \min_j R_j$, $R^- = \max_j R_j$

The solutions calculated by S^* and R^* are with a maximum group utility and minimum individual regret of the opponent respectively. υ is the weight of the strategy of the majority of criteria.

- Sorting the values of S, R, Q in decreasing order to rank the alternatives. The results are illustrated in three ranking lists.
- The alternative (a') is considered the best by the measure (Q) if the below two conditions are satisfied.

- Acceptable benefit; $Q(a'') - Q(a') \geq 1/(1/(J-1)$

where a'' is the alternative with the second position in the ranking list by Q

- For acceptable stability in decision making, alternative a' must be the best ranked by S or / and R

If one condition is not satisfied, a set of compromise solutions is proposed.

- Alternatives a' and a'' if only condition 2 is not satisfied.
- Alternatives a' and a'' and a^M if condition 1 is not satisfied. a^M is determined by the relation $Q(a^M) - Q(a') < 1/(J-1)$ for maximum M (the positions of these alternatives are in closeness) [14, 18].

MATERIALS AND METHODS

The average fiber length, micronaire and maturity index were 27mm, 3.6 and 0.85 respectively. Cotton fibers were furnished as a second draw frame sliver with linear density of 5.2ktex to produce 30Ne yarn on a Rieter RU04 rotor spinning machine with 900T/m. The opening roller was designed at a speed of 8200rpm. The 35mm diameter rotor worked at a speed of 75000rpm. There were three main parameters in draw frame including delivery speed of 550, 650, 700 and 750m/min, distance between back and middle rolls of 8, 10, 12 and 14mm and break draft of 1.14, 1.41 and 1.70. Specifications of the yarn samples have been shown in Table 1.

A test specimen of 500mm was elongated at an extension rate of 500mm/min to examine load-elongation characteristics using Uster Tensorapid3. The unevenness

Table 1: Specifications of cotton rotor yarn samples

	Variables				Variables				Variables		
Alt	DBBMR	DS	BD	Alt	DBBMR	DPS	BD	Alt	DBBMR	DS	BD
A1	8	750	1.70	A17	10	550	1.41	A33	10	750	1.70
A2	14	750	1.41	A18	10	750	1.14	A34	8	550	1.41
A3	14	550	1.41	A19	12	650	1.70	A35	8	650	1.14
A4	14	550	1.70	A20	10	650	1.14	A36	10	550	1.70
A5	12	550	1.70	A21	8	550	1.70	A37	12	750	1.70
A6	8	700	1.70	A22	10	700	1.41	A38	14	650	1.41
A7	12	650	1.14	A23	8	700	1.41	A39	14	650	1.70
A8	8	650	1.70	A24	10	700	1.70	A40	10	650	1.70
A9	12	700	1.41	A25	14	750	1.14	A41	12	650	1.41
A10	10	700	1.14	A26	8	700	1.14	A42	14	700	1.41
A11	12	750	1.41	A27	14	700	1.41	A43	14	700	1.14
A12	14	750	1.70	A28	8	650	1.41	A44	10	650	1.41
A13	10	750	1.41	A29	14	550	1.14	A45	8	550	1.14
A14	12	750	1.14	A30	14	650	1.14	A46	10	550	1.14
A15	12	700	1.70	A31	12	550	1.14	A47	12	550	1.41
A16	8	750	1.41	A32	12	700	1.14	A48	10	550	1.14

Alt: alternatives DBBMR: distance between back and middle rolls (mm) DS: delivery speed (m/min) BD: break draft

Table 2: Quality parameters of the yarns (Performance values of the alternatives)

	Y.T	B.E	CV%	T.P	T.P	Y.N	Y.H		Y.T	B.E	CV%	T.P	T.P	Y.N	Y.H
Alt	X_6^+	X_7^+	X_1^-	X_2^-	X_3^-	X_4^-	X_5^-	Alt	X_6^+	X_7^+	X_1^-	X_2^-	X_3^-	X_4^-	X_5^-
A1	15.06	6.80	14.56	25.20	62.40	31.20	6.54	25	A25	14.98	6.59	14.94	36.40	66.20	35.80
A2	14.90	6.65	14.65	28.80	56.00	35.80	5.19	26	A26	15.39	6.73	14.85	34.80	71.60	49.60
A3	13.00	6.24	15.13	41.80	81.20	49.40	5.79	27	A27	14.54	6.42	14.54	25.40	53.60	21.60
A4	15.25	6.68	14.78	37.20	43.80	19.60	6.48	28	A28	14.59	6.43	14.51	35.00	50.00	28.60
A5	14.70	6.67	14.65	25.20	54.20	24.20	4.99	29	A29	12.77	6.67	14.57	28.00	73.50	36.00
A6	14.28	6.80	14.38	28.20	46.80	23.00	5.09	30	A30	15.46	6.83	15.05	35.50	92.00	71.00
A7	13.42	6.45	14.93	41.40	70.20	33.40	5.62	31	A31	13.97	6.65	15.10	45.50	75.00	39.50
A8	14.10	6.67	14.68	35.80	35.80	31.80	5.33	32	A32	13.62	6.50	15.30	43.50	82.00	26.00
A9	12.63	6.27	15.11	38.20	38.20	49.20	5.13	33	A33	13.34	6.58	14.92	38.50	67.50	28.50
A10	13.00	6.70	14.58	30.20	30.20	27.40	5.75	34	A34	14.05	6.72	14.78	26.50	73.50	31.50
A11	12.89	6.42	14.73	34.40	63.80	31.60	5.25	35	A35	14.58	6.78	15.61	34.50	57.00	33.00
A12	14.02	6.71	15.01	34.80	53.20	34.00	6.41	36	A36	14.11	6.61	14.70	32.50	60.00	34.00
A13	13.36	6.17	14.68	32.60	63.20	30.80	5.70	37	A37	14.46	6.73	15.11	43.50	74.50	49.00
A14	14.80	6.28	14.92	51.60	72.20	38.20	5.75	38	A38	13.38	6.43	14.65	33.00	60.00	30.90
A15	14.22	6.35	14.71	29.40	59.60	25.20	5.73	39	A39	13.33	6.51	15.31	55.00	98.50	64.50
A16	14.64	6.46	14.21	20.80	40.60	22.40	5.58	40	A40	14.65	6.43	14.71	42.00	75.00	39.50
A17	13.99	6.28	15.09	34.40	82.20	65.60	5.68	41	A41	15.13	6.76	14.81	30.00	71.16	26.00
A18	15.20	6.63	14.48	16.20	50.40	29.00	5.39	42	A42	13.22	6.47	14.97	34.50	73.00	46.00
A19	13.85	6.40	14.66	36.40	60.40	33.20	5.71	43	A43	12.85	6.61	14.74	32.50	64.50	36.00
A20	13.85	6.41	14.35	23.20	46.60	28.80	5.40	44	A44	13.96	6.63	14.58	24.00	56.00	27.00
A21	13.98	6.39	14.70	30.80	64.20	34.80	5.12	45	A45	14.07	6.57	14.42	19.00	51.50	19.50
A22	15.21	6.56	14.24	26.20	48.20	26.80	6.58	46	A46	14.98	6.72	14.45	24.50	59.00	31.00
A23	14.25	6.33	15.18	40.20	94.40	71.80	5.74	47	A47	14.13	6.40	14.47	24.50	54.50	28.50
A24	14.70	6.53	14.66	26.20	56.20	30.40	5.20	48	A48	13.23	6.37	14.45	22.50	50.50	23.50

Y.T: yarn tenacity (cN/tex) B.E: breaking elongation (%) CV: coefficient of mass variation (%) T.P: thin places (-50%) T.P: thick places (+50%) Y.N: yarn neps (+280%) Y.H: yarn hairiness (H)

and imperfections of 5 samples for each group were measured with an Uster Tester 4 with a test speed of 400 m/min for 2.5min. The hairiness of 10 samples with length of 100mm was measured with Premier Tester 7000. Table 2 shows the results of the experiments.

RESULTS

Performing TOPSIS Approach: A one-way ANOVA test (5% significance level) was applied to determine the effects of considered parameters on yarn quality parameters. Average values of the yarn quality parameters were grouped according to the Duncan Multiple Range Test.

The mechanical and physical properties of a yarn running into a circular knitting machine are important technological parameter that affects machine efficiency. Higher tenacity and elongation at break of the yarn and lower friction between yarn and machine surfaces such as needle are useful to reduce yarn breakage. Hairiness is a factor that affects friction between needle and yarn. Increase in hairiness and wrapper fibers, produces more friction between the yarn and metal surface and increase yarn bending flexural rigidity. Increase in friction leads to an increase in yarn tension and breakage [19-22]. However, mechanical properties of a yarn are a function of yarn imperfections and unevenness. The more the imperfections and unevenness are the more yarn breakages occur [23].

If a ranking between these properties is needed the most important one to increase machine efficiency is assumed to be yarn hairiness followed by unevenness, thick places, neps, thin places, tenacity and elongation. Tenacity and elongation are shown by positive sign. Also, hairiness, coefficient of mass variation (CV%) and imperfections are shown by negative sign in the investigation.

Relative importance of the effective factors on machine efficiency was picked up based on the 24 experts, opinions that were proficient in weft knitting industry. Table 3 shows results of the discussion about importance of the rotor yarn properties and relative importance of each criterion.

The decision matrix obtained from average values of yarn quality parameters has been shown in Table 2. At the next step normalized decision matrix was calculated using

Table 3: Intensity of the effect of yarn properties on weft knitting machine efficiency

Company	Y.T	B.E	Y.H	CV	TP	TP	Y.N
Relative or mean importance (RI_j)	7.375	3.875	9.875	9.750	9.750	4.625	9.250
Weight of each criterion ($RI_j / \sum_{j=1}^{j=n} RI_j$)	0.085	0.075	0.191	0.189	0.189	0.089	0.179

Table 4: The normalized decision matrix

	Y.T	B.E	Y.H	CV	TP	TP	Y.N		Y.T	B.E	Y.H	CV	TP	TP	Y.N
Alt	X_6^+	X_7^+	X_1^-	X_2^-	X_3^-	X_4^-	X_5^-	Alt	X_6^+	X_7^+	X_1^-	X_2^-	X_3^-	X_4^-	X_5^-
A1	0.150	0.150	0.142	0.107	0.140	0.120	0.167	25	A25	0.149	0.145	0.146	0.155	0.149	0.138
A2	0.149	0.146	0.143	0.123	0.126	0.138	0.132	26	A26	0.154	0.148	0.145	0.149	0.161	0.192
A3	0.130	0.137	0.147	0.179	0.183	0.191	0.147	27	A27	0.145	0.141	0.142	0.108	0.121	0.083
A4	0.152	0.147	0.144	0.159	0.098	0.075	0.165	28	A28	0.145	0.141	0.141	0.149	0.112	0.110
A5	0.147	0.147	0.143	0.107	0.122	0.093	0.127	29	A29	0.127	0.147	0.142	0.119	0.166	0.139
A6	0.142	0.149	0.140	0.120	0.105	0.089	0.129	30	A30	0.154	0.150	0.147	0.152	0.207	0.275
A7	0.134	0.142	0.145	0.177	0.158	0.129	0.143	31	A31	0.139	0.146	0.147	0.194	0.169	0.153
A8	0.141	0.147	0.143	0.153	0.080	0.123	0.136	32	A32	0.136	0.143	0.149	0.186	0.185	0.100
A9	0.126	0.138	0.147	0.163	0.086	0.190	0.130	33	A33	0.133	0.145	0.145	0.164	0.152	0.110
A10	0.130	0.147	0.142	0.129	0.068	0.106	0.146	34	A34	0.140	0.148	0.144	0.113	0.166	0.122
A11	0.128	0.141	0.143	0.147	0.144	0.122	0.134	35	A35	0.145	0.149	0.152	0.147	0.128	0.127
A12	0.140	0.147	0.146	0.149	0.120	0.131	0.163	36	A36	0.141	0.145	0.143	0.139	0.135	0.131
A13	0.133	0.136	0.143	0.139	0.142	0.119	0.145	37	A37	0.144	0.148	0.147	0.186	0.168	0.189
A14	0.148	0.138	0.145	0.221	0.163	0.148	0.146	38	A38	0.133	0.141	0.143	0.141	0.135	0.119
A15	0.142	0.140	0.143	0.125	0.134	0.097	0.146	39	A39	0.133	0.143	0.149	0.235	0.222	0.250
A16	0.146	0.142	0.138	0.089	0.091	0.086	0.142	40	A40	0.146	0.141	0.143	0.179	0.169	0.153
A17	0.139	0.138	0.147	0.147	0.185	0.254	0.145	41	A41	0.151	0.149	0.144	0.128	0.160	0.100
A18	0.152	0.146	0.141	0.069	0.113	0.112	0.137	42	A42	0.132	0.142	0.146	0.147	0.164	0.178
A19	0.138	0.141	0.143	0.155	0.136	0.128	0.145	43	A43	0.128	0.145	0.144	0.139	0.145	0.139
A20	0.138	0.141	0.140	0.099	0.105	0.111	0.137	44	A44	0.139	0.146	0.142	0.102	0.126	0.104
A21	0.139	0.140	0.143	0.131	0.145	0.134	0.130	45	A45	0.140	0.144	0.140	0.081	0.116	0.075
A22	0.152	0.144	0.139	0.112	0.108	0.103	0.168	46	A46	0.149	0.148	0.141	0.104	0.133	0.120
A23	0.142	0.139	0.148	0.172	0.213	0.278	0.146	47	A47	0.141	0.141	0.141	0.104	0.123	0.110
A24	0.147	0.143	0.143	0.112	0.126	0.117	0.132	48	A48	0.132	0.140	0.141	0.096	0.114	0.091

data shown in Table 2. Normalized decision matrix has been shown in Table 4. Considering the different importance of each criterion and calculating vector of the criteria, the weighted normalized decision matrix was constructed using Equation 2. Calculated matrix has been shown in Table 5.

At the fifth step of the TOPSIS method, the positive and the negative ideal solution (A^+) and (A^-) were determined. Values of (A^+) and (A^-) have been shown below as two vectors.

After identifying (A^+) and (A^-) the separation of each alternative from the ideal solution are given. Distance of each alternative from the ideal solution can be seen in Table 7. Relative closeness of the alternatives (CC_j) to the ideal solution (A_j) were defined by the last equation with respect to A^+. Results of calculation are shown in Table 8.

Performing VIKOR Approach: Relative importance of the criteria considered from one to ten and decision matrix were the same for both algorithms. Considering the different importance of each criterion and calculating vector of the criteria, the normalized decision matrix was constructed using linear normalization technique for VIKOR method. Calculated matrix has been shown in Table 9.

The first step in decision making using VIKOR approach is obtaining the best and the worst values for each criterion functions. At the second step the values of S_j and R_j, $j = 1,2,...,J$ are calculated based on the Equations 9, 10 and weight of each criterion when $_{[R5]}\upsilon = 0.50$. As mentioned above, υ is the weight of the strategy of the majority of criteria. Here we can use $\upsilon = 0.50$ for final ranking. Table 10 shows the values of Q_j, S_j and R_j when $\upsilon = 0.50_{[R6]}$.

Table 5: The weighted normalized decision matrix

	Y.T	B.E	Y.H	CV	TP	TP		Y.N	Y.T	B.E	Y.H	CV	TP	TP	Y.N
Alt	X_6^+	X_7^+	X_1^-	X_2^-	X_3^-	X_4^-	Alt	X_5^-	X_6^+	X_7^+	X_1^-	X_2^-	X_3^-	X_4^-	X_5^-
1	0.012	0.011	0.026	0.009	0.026	0.021	25	0.032	25	0.012	0.010	0.027	0.014	0.028	0.024
2	0.012	0.011	0.027	0.011	0.023	0.024	26	0.025	26	0.013	0.011	0.027	0.013	0.030	0.034
3	0.011	0.010	0.028	0.016	0.034	0.034	27	0.028	27	0.012	0.010	0.026	0.009	0.022	0.015
4	0.012	0.011	0.027	0.014	0.018	0.013	28	0.031	28	0.012	0.010	0.026	0.013	0.021	0.019
5	0.012	0.011	0.027	0.009	0.023	0.016	29	0.024	29	0.010	0.011	0.026	0.010	0.031	0.025
6	0.012	0.011	0.026	0.010	0.020	0.016	30	0.024	30	0.013	0.011	0.027	0.013	0.039	0.049
7	0.011	0.010	0.027	0.015	0.030	0.023	31	0.027	31	0.011	0.011	0.027	0.017	0.032	0.027
8	0.011	0.011	0.027	0.013	0.015	0.022	32	0.026	32	0.011	0.010	0.028	0.016	0.035	0.018
9	0.010	0.010	0.027	0.014	0.016	0.034	33	0.025	33	0.011	0.010	0.027	0.014	0.028	0.019
10	0.011	0.011	0.026	0.011	0.012	0.019	34	0.028	34	0.011	0.011	0.027	0.010	0.031	0.021
11	0.010	0.010	0.027	0.013	0.027	0.022	35	0.025	35	0.012	0.011	0.028	0.013	0.024	0.022
12	0.011	0.011	0.027	0.013	0.022	0.023	36	0.031	36	0.011	0.010	0.027	0.012	0.025	0.023
13	0.011	0.010	0.027	0.012	0.027	0.021	37	0.027	37	0.012	0.011	0.027	0.016	0.031	0.034
14	0.012	0.010	0.027	0.019	0.030	0.026	38	0.028	38	0.011	0.010	0.027	0.012	0.025	0.021
15	0.012	0.010	0.027	0.011	0.025	0.017	39	0.028	39	0.011	0.010	0.028	0.021	0.042	0.044
16	0.012	0.010	0.026	0.008	0.017	0.015	40	0.027	40	0.012	0.010	0.027	0.016	0.032	0.027
17	0.011	0.010	0.027	0.013	0.035	0.045	41	0.027	41	0.012	0.011	0.027	0.011	0.030	0.018
18	0.012	0.011	0.026	0.006	0.021	0.020	42	0.026	42	0.011	0.010	0.027	0.013	0.031	0.032
19	0.011	0.010	0.027	0.014	0.025	0.023	43	0.027	43	0.010	0.010	0.027	0.012	0.027	0.025
20	0.011	0.010	0.026	0.008	0.019	0.020	44	0.026	44	0.011	0.011	0.026	0.009	0.023	0.018
21	0.011	0.010	0.027	0.011	0.0274	0.024	45	0.025	45	0.011	0.010	0.026	0.007	0.022	0.013
22	0.012	0.010	0.026	0.010	0.020	0.018	46	0.032	46	0.012	0.011	0.026	0.009	0.025	0.021
23	0.01	0.010	0.028	0.015	0.040	0.050	47	0.028	47	0.012	0.010	0.026	0.009	0.023	0.019
24	0.012	0.010	0.027	0.010	0.024	0.021	48	0.025	48	0.011	0.010	0.026	0.008	0.021	0.016

Table 6: Values of positive and negative ideal solution

	CV	T.P	T.P	Y.N	Y.H	T	B.E
Ideal solution	X_1^-	X_2^-	X_3^-	X_4^-	X_5^-	X_6^+	X_7^+
A^+	0.026	0.006	0.012	0.013	0.024	0.013	0.011
A^-	0.028	0.021	0.042	0.050	0.032	0.010	0.010

Table 7: Distance of each alternative from the positive and negative ideal solution

Alt	(D^+)	(D^-)	Alt	(D^+)	(D^-)	Alt	(D^+)	(D^-)	Alt	(D^+)	(D^-)
A1	0.020	0.034	A13	0.020	0.034	A25	0.022	0.030	A37	0.031	0.021
A2	0.018	0.033	A14	0.028	0.026	A26	0.031	0.021	A38	0.019	0.035
A3	0.033	0.018	A15	0.017	0.038	A27	0.016	0.042	A39	0.046	0.008
A4	0.015	0.044	A16	0.010	0.045	A28	0.015	0.038	A40	0.028	0.025
A5	0.014	0.041	A17	0.041	0.012	A29	0.024	0.030	A41	0.020	0.036
A6	0.012	0.043	A18	0.014	0.040	A30	0.047	0.009	A42	0.029	0.024
A7	0.024	0.030	A19	0.020	0.033	A31	0.028	0.026	A43	0.022	0.031
A8	0.015	0.040	A20	0.013	0.040	A32	0.028	0.033	A44	0.015	0.039
A9	0.025	0.032	A21	0.021	0.032	A33	0.023	0.034	A45	0.013	0.044
A10	0.013	0.044	A22	0.015	0.040	A34	0.023	0.032	A46	0.017	0.036
A11	0.021	0.033	A23	0.048	0.008	A35	0.019	0.034	A47	0.016	0.038
A12	0.019	0.034	A24	0.016	0.037	A36	0.019	0.033	A48	0.014	0.042

Table 8: Relative closeness coefficient of each alternative to the ideal solution

Alt	(CCj)	Alt	(CC_j)	Alte	(CC_j)	Alt	(CC_j)
A1	0.635	A13	0.628	A25	0.577	A37	0.398
A2	0.645	A14	0.490	A26	0.408	A38	0.648
A3	0.356	A15	0.692	A27	0.726	A39	0.144
A4	0.749	A16	0.815	A28	0.716	A40	0.474
A5	0.745	A17	0.233	A29	0.552	A41	0.637
A6	0.777	A18	0.746	A30	0.155	A42	0.452
A7	0.557	A19	0.617	A31	0.484	A43	0.585
A8	0.732	A20	0.747	A32	0.543	A44	0.717
A9	0.562	A21	0.606	A33	0.596	A45	0.774
A10	0.773	A22	0.727	A34	0.588	A46	0.676
A11	0.619	A23	0.137	A35	0.647	A47	0.708
A12	0.634	A24	0.692	A36	0.630	A48	0.750

Table 9: The normalized decision matrix

	Y.T	B.E	CV	T.P	T.P	Y.N	Y.H		Y.T	B.E	CV	T.P	T.P	Y.N	Y.H
	------	------	------	------	------	-----	-------		------	------	------	------	-----	------	------
Alt	X6+	X7+	X1-	X2-	X3-	X4-	X5-	Alt	X6+	X7+	X1-	X2-	X3-	X4-	X5-
A1	0.974	0.996	0.975	0.642	0.483	0.625	0.755	A25	0.968	0.965	0.950	0.445	0.456	0.544	0.923
A2	0.964	0.973	0.969	0.562	0.539	0.544	0.951	A26	0.996	0.985	0.957	0.465	0.421	0.393	0.745*
A3	0.840	0.913	0.939	0.387	0.371	0.394	0.853	A27	0.940	0.939	0.977	0.637	0.563	0.902	0.754
A4	0.986	0.979	0.961	0.435	0.689	0.994	0.762	A28	0.943	0.941	0.979	0.462	0.604	0.681	1.000**
A5	0.950	0.977	0.969	0.642	0.557	0.805	0.989	A29	0.826	0.977	0.975	0.578	0.410	0.541	0.948
A6	0.923	0.995	0.988	0.574	0.645	0.847	0.970	A30	1.000*	1.000*	0.944	0.456	0.328	0.274	0.749
A7	0.868	0.944	0.951	0.391	0.430	0.583	0.879	A31	0.903	0.973	0.941	0.356	0.402	0.493	0.955
A8	0.912	0.977	0.967	0.452	0.843	0.613	0.926	A32	0.880	0.952	0.928	0.372	0.368	0.750	0.753
A9	0.816**	0.918	0.940	0.424	0.790	0.396	0.962	A33	0.862	0.964	0.952	0.420	0.447	0.684	0.754
A10	0.840	0.980	0.974	0.536	1.000**	0.711	0.859	A34	0.908	0.983	0.961	0.611	0.410	0.619	0.880
A11	0.833	0.939	0.964	0.470	0.473	0.617	0.940	A35	0.943	0.992	0.910*	0.469	0.529	0.590	0.948
A12	0.907	0.982	0.946	0.465	0.567	0.573	0.770	A36	0.912	0.967	0.966	0.498	0.503	0.573	0.968
A13	0.864	0.903**	0.968	0.496	0.477	0.633	0.866	A37	0.935	0.985	0.940	0.372	0.405	0.397	0.932
A14	0.957	0.920	0.952	0.313	0.418	0.510	0.859	A38	0.866	0.941	0.970	0.490	0.503	0.631	0.946
A15	0.920	0.929	0.966	0.551	0.506	0.773	0.862	A39	0.862	0.953	0.928	0.294*	0.306*	0.302	0.908
A16	0.947	0.945	1.000**	0.778	0.743	0.870	0.885	A40	0.947	0.941	0.965	0.385	0.402	0.493	0.757
A17	0.904	0.919	0.941	0.470	0.367	0.297	0.869	A41	0.978	0.990	0.959	0.540	0.424	0.750	0.932
A18	0.983	0.970	0.981	1.000**	0.599	0.672	0.916	A42	0.855	0.948	0.949	0.469	0.413	0.423	0.950
A19	0.895	0.936	0.969	0.445	0.500	0.587	0.865	A43	0.831	0.967	0.963	0.498	0.468	0.541	0.953
A20	0.896	0.939	0.990	0.698	0.648	0.677	0.914	A44	0.902	0.970	0.974	0.675	0.539	0.722	0.964
A21	0.904	0.935	0.966	0.525	0.470	0.560	0.964	A45	0.910	0.961	0.985	0.852	0.586	1.000**	0.896
A22	0.984	0.960	0.997	0.618	0.626	0.727	0.750	A46	0.968	0.983	0.983	0.661	0.511	0.629	0.919
A23	0.921	0.926	0.936	0.402	0.319	0.271*	0.860	A47	0.913	0.936	0.982	0.661	0.554	0.684	0.872
A24	0.951	0.955	0.969	0.618	0.537	0.641	0.950	A48	0.855	0.932	0.983	0.720	0.598	0.829	0.862

** Shows the worst value and * shows the best value for the criterion

Comparing Final Ranking of the Alternatives and Discussion: The results of TOPSIS analysis are summarized in Table 8 and Figure 2. Based on the CC_j values ranking of the preference order of all alternatives in descending order is as below. According to the last step, the best alternative is selected as sample No.16 with closeness coefficient of 0.815 and the worst alternative is sample No.23 with closeness coefficient of 0.137. According to the final ranking, yarn sample spun at processing condition in which distance between back and middle rolls is 8 mm, delivery speed is 750m/min and break draft is 1.41 has the best performance.

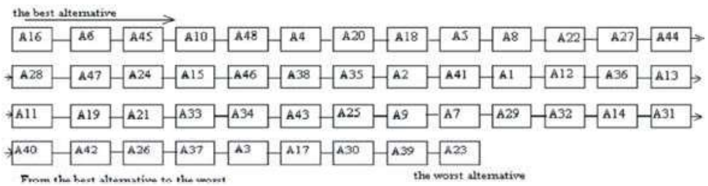

Fig. 2: Ranking the preference order (descending) of all alternatives

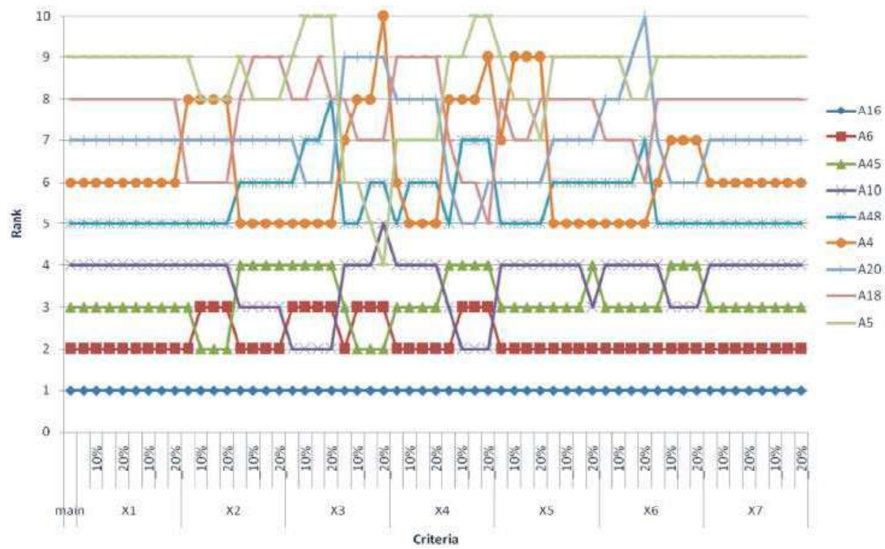

Fig. 3: Ranking the preference order of more important alternatives after sensitivity analysis

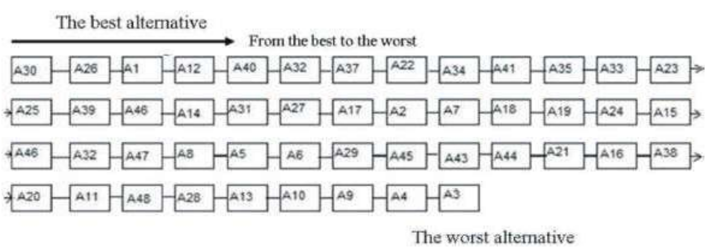

Fig. 4: Ranking the preference order (descending) of all alternatives

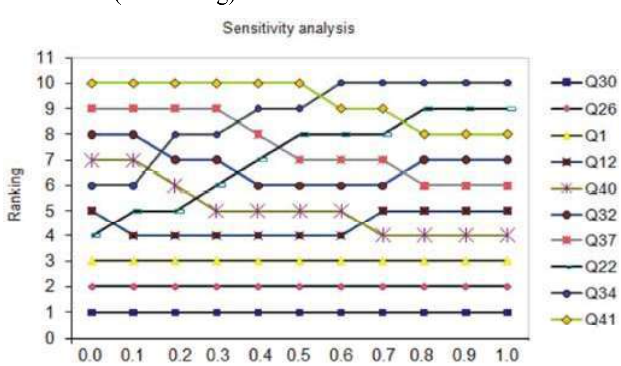

Fig. 5: Ranking the preference order of 10 important alternatives after sensitivity analysis

Values of the relative importance are expressed by decision makers. Since, this parameter is not certainly stable, it is important to know the effect of deviation in these values on final ranking. To test this influence, sensitivity analysis is conducted. The idea of sensitivity analysis is decreasing and increasing all the weights of the criteria (5%, 10%, 15%, 20%) according to the Equation 12 and repeating TOPSIS approach with new values.

$$W_i^{new} = W_i \pm \alpha W_i \text{ and } \alpha = \{0.05, 0.1, 0.15, 0.2\} \qquad (12)$$

The main condition in Table 8 expresses the original result of the case study. Figure 3 illustrates the graphical representation for only 9 more important alternatives of these results that were in prior final ranking due to limitation. According to the Figure, it was concluded that, ranking of 4 more important alternatives (A16, A6, A45, A10) is approximately as same as previous main ranking. Alternatives show a straight or nearly straight line trend and their position in new ranking is stable while considered weight for each yarn property changes.

The results of VIKOR analysis are summarized in Table 10 and Figure 4. Based on the values of S, R, Q ranking of the preference order of all alternatives in descending order is as below (descending order).

According to the last step, the best alternative for weft knitting machine is selected as sample No.30 with Q_j, S_j and R_j of 0, 0.058, 0.031 respectively and the worst alternative is sample No.3 with Q_j, S_j and R_j of 0.830, 0.478 and 0.774. On the other hand, according to the final ranking, yarn sample spun at processing condition in which distance between back and middle rolls was 14mm, delivery speed was 650m/min and break draft is 1.14 had the best performance. It means it is expected that if this yarn sample is used in a circular knitting machine to produce fabric, the knittability is higher while there be less yarn breakage as well.

Sensitivity analysis is conducted by changing values of υ or the weight of the strategy of the majority of criteria. The idea of sensitivity analysis is decreasing and increasing υ value from zero to one by step of 0.1. The main condition in Table 10 expresses the original result of the case study. Figure 5 illustrates the graphical representation for these alternatives due to space limitation. According to the sensitivity analysis results, ranking of more important alternatives (A30, A26, A1, A12) is approximately as same as previous main ranking. Alternatives show a straight or nearly straight line trend and their position in new ranking is stable while considered υ for each yarn property changes.[R8]

Findings of the research confirm the effect of difference in TOPSIS and VIKOR procedure steps on final ranking of the alternatives. Aggregation function and normalization methods for eliminating the units of criterion function used by TOPSIS and VIKOR techniques are different. Linear normalization employed by VIKOR is independent of the evaluation unit of a criterion. Normalized values proposed by vector normalization in TOPSIS are different when different evaluation unit is used in a particular criterion.

The relative importance of all criteria and a balance between total and individual satisfaction are considered when an aggregating function is represented by VIKOR. This case in not taken into account when aggregating function is represented by TOPSIS. Final ranking proposed by VIKOR is acceptable only for the given set of alternatives [8]. Also, VIKOR approach determines the

Table 10: Values of Q_j, S_j and R_j for $\upsilon = 0.50$[R7]

Alt	Q_j	S_j	R_j	Alt	Q_j	S_j	R_j	Alt	Q_j	S_j	R_j
A1	0.154	0.229	0.061	A17	0.365	0.414	0.159	A33	0.302	0.354	0.134
A2	0.368	0.422	0.153	A18	0.391	0.474	0.127	A34	0.295	0.376	0.100
A3	0.830	0.478	0.774	A19	0.395	0.480	0.125	A35	0.301	0.340	0.150
A4	0.663	0.324	0.707	A20	0.497	0.610	0.126	A36	0.422	0.481	0.166
A5	0.450	0.502	0.181	A21	0.469	0.543	0.163	A37	0.270	0.311	0.138
A6	0.453	0.518	0.167	A22	0.274	0.359	0.087	A38	0.484	0.573	0.149
A7	0.381	0.461	0.128	A23	0.304	0.348	0.145	A39	0.314	0.370	0.135
A8	0.445	0.526	0.146	A24	0.417	0.486	0.152	A40	0.241	0.293	0.116
A9	0.599	0.693	0.179	A25	0.305	0.360	0.132	A41	0.296	0.343	0.138
A10	0.539	0.608	0.189	A26	0.073	0.142	0.044	A42	0.429	0.501	0.152
A11	0.504	0.586	0.163	A27	0.353	0.432	0.119	A43	0.464	0.534	0.165
A12	0.234	0.306	0.091	A28	0.513	0.576	0.189	A44	0.465	0.537	0.163
A13	0.520	0.583	0.191	A29	0.455	0.519	0.170	A45	0.459	0.573	0.112
A14	0.343	0.386	0.158	A30	0.000	0.058	0.031	A46	0.335	0.401	0.129
A15	0.420	0.501	0.139	A31	0.346	0.392	0.156	A47	0.434	0.530	0.125
A16	0.479	0.593	0.119	A32	0.261	0.318	0.116	A48	0.509	0.625	0.141

weight stability intervals [14]. Researcher believed that, selecting appropriate MCDM algorithm to rank feasible alternatives and accepting proposed sample and condition is related to economical advantages and knitting machine performance while producing yarn and knitted fabric samples.

CONCLUSION

The purpose of the study is to compare performances of TOPSIS and VIKOR approaches in obtaining suitable spinning condition for rotor spun yarn. Qualitative parameters of the forty eight different yarn samples were assessed. Then, these characteristics were evaluated with the purpose of using the yarn in weft knitted fabric and to increase machine efficiency. Relative steps of the TOPSIS and VIKOR algorithms were executed for available data and finally the ranking of the alternatives were performed. Based on the final ranking represented by TOPSIS yarn sample spun when distance between back and middle rolls is 8 mm, delivery speed is 750m/min and break draft is 1.41 has the best performance among available alternatives. VIKOR method showed that, yarn sample spun at processing condition in which distance between back and middle rolls is 14mm, delivery speed is 650m/min and break draft is 1.14 is the most preferred one among the alternatives for knitting process. Difference between proposed rankings can be due to normalization method applied in these algorithms. Selection of the best alternative is depended to the economical advantages in yarn and fabric production and also, ease of spinning preparation machines setting.

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