(REFEREED RESEARCH)

THE APPLICATION OF SEWING MACHINE SELECTION WITH THE MULTI-OBJECTIVE OPTIMIZATION ON THE BASIS OF RATIO ANALYSIS METHOD (MOORA) IN APPAREL SECTOR

KONFEKSİYON SEKTÖRÜNDE ORAN ANALİZİ BAZINDA ÇOK AMAÇLI OPTİMİZASYON YÖNTEMİ (MOORA) İLE DİKİŞ MAKİNESİ SEÇİMİ UYGULAMASI

İrfan ERTUĞRUL, Tayfun ÖZTAŞ

Pamukkale University, Business Administration Department, Denizli, Turkey

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ABSTRACT

There are a lot of different operations in transformation process from fiber to garment. Sewing is the last stage of this process and sewing machine is the most important tool in this process. In terms of competition in the market, the machines have to be optimal level in speed, price, energy consumption etc. subjects which will be purchased. Therefore, Multi-Objective Optimization on the Basis of Ratio Analysis Method (MOORA) is used in this paper which is one of the newest multi objective/criteria decision making methods and attained results were compared with Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) after that optimal machine was selected.

Keywords: Apparel, Machine Selection, MOORA, TOPSIS, Multi-Objective Decision Making.

ÖZET

İplikten giysiye ulaşan süreçte birçok farklı işlem bulunmaktadır. Bu sürecin son adımı dikiş aşamasında kullanılan en önemli araç dikiş makinesidir. Piyasalardaki rekabet koşulları nedeniyle konfeksiyon sektöründe satın alınacak makinaların hız, fiyat enerji tüketimi gibi konularda optimal seviyede olması gerekmektedir. Bu nedenle bu çalışmada en yeni çoklu kriterli karar verme yöntemlerinden MOORA kullanılmıştır ve elde edilen sonuçlar TOPSIS yöntemiyle karşılaştırılıp optimal makine seçilmiştir.

Anahtar Kelimeler: Konfeksiyon, Makine Seçimi, MOORA, TOPSIS, Çok Amaçlı Karar Verme.

Corresponding Author: İrfan Ertuğrul, iertugrul@pau.edu.tr, Tel: +90 258 296 26 74

1. INTRODUCTION

In response to mankind rule whole the world with their intelligence, in fact they are vulnerable creatures. For example, by the reason of the fact that they do not have a fur on their body which may protect from cold climate, they have to make provisions against these climates. Because of these reasons primarily clothing and then textile concepts emerged. Textile is a process which starts with manufacturing fibre and finishes after related operations with each other when productions delivered to consumers (1).

Apparel is a branch of industry which the products are processed lastly as garment or household goods before they are delivered to consumers. In this step, fabrics are sewed according to desired size and shape and then productions are completed. Textile sector is very important for Turkish economy in terms of employment and exporting. For example, last 6 years' import data based on the export by standard international trade classification (SITC.Rev.3) report which were published by Turkish Statistical Institute as below (2).

Table 1. Total imports of Turkey and proportion of textile sector by year (thousand $)

Year	Total Imports	Imports of Textile Production	Proportion of Textile in Imports	Variation from previous year
2014*	131 391 577	12 839 284	9.77%	0.62%
2013	151 802 637	14 740 647	9.71%	11.61%
2012	152 461 737	13 259 405	8.70%	-9.19%
2011	134 906 869	12 920 412	9.58%	-0.21%
2010	113 883 219	10 932 274	9.60%	2.56%
2009	102 142 613	9 559 339	9.36%	-

* Data with October 2014

Sewing machine is dominated garment industry from past to present which is a simple and long-lived tool. Primitive sewing tools like needle and awl were made from bone, fish bone, wood, bronze and etc. These tools also reflect the characteristics of that era; today's machines have become dependent on technology in recent years due to the microprocessor revolution. The first initiatives for steel needles and sewing machine were made by Weisenthal in 1750. Thomas Saint appealed patent for a machine which can sew only chain stitch. In 1830, 80 sewing machines were produced by Barthelmy Thimmonnier. These machines could sew various type stitches and these machines worried tailors due to losing their jobs. Then, sewing machine sales increased considerably. Sewing speed, durability, efficiency and similar issues have been become crucial for sewing machines in time (3). For this reason, it is aimed to sewing machine selection for apparel sector with multi-objective (criteria) decision making methods.

Decision makers decide on different issues every day. As decision making, desired features must be in maximum amounts and undesired features must be in minimum amounts. Therefore, decision making process is a branch of operations research. Main problems are process differences, a small number of measurable variables in the same manner, the conflicting interests and constraints in decision making stage. Different decision makers' different thoughts on alternatives makes difficult to decision making. Decision making process describes alternatives and interests results of selecting one of them in engineering level (4). Main steps of this process can be listed as below (5).

- Determine assessment criteria about system constraints for goals
- Determine alternatives to reach goals
- Evaluating alternatives in terms of criteria
- Using feasible methods for sampling
- Select an alternative as optimal
- If result is not accepted, collect more data and repeat these steps.

Multi-criteria decision making methods are used for ranking solutions, create portfolio, performance evaluating and purchasing problems in businesses (6) and selecting subcontractor (7) etc. subjects. Decision making methods could be classified with regard to information obtained for decision makers (8):

- Group methods based quantitative measurements: It uses multi-criteria utility theory and heuristic methods.
- Group methods based qualitative measurements initially: Qualitative measurements initially are transformed quantitative measurement with analytic hierarchy methods. Fuzzy measurements are included this group.
- Methods that used more than indicator based on quantitative measurements: Alternatives are compared according to superiority.
- Methods based on qualitative methods and not transformed quantitative data: Decisions making according to verbal analysis.

2. MATERIAL AND METHOD

It is aimed that selecting optimal sewing machine used in apparel sector with multi-criteria decision making methods in this paper. For this reason six sewing machines which sew straight stitch were selected as alternatives and stitch speed, price, energy consumption, maximum stitch length properties were selected as criteria.

- Stitch Speed: To increase production quantity, it needs more sewing in unit time. So, maximum stitch speed for medium weight materials was analyzed in per minute.
- Price: To keep profitability at maximum level, costs must be kept at minimum level as investing. As machines selected, currency was selected as Turkish Lira. Machines were selected at similar prices as possible as. Average of prices in the market was used for objectivity.
- Energy consumption: Energy consumption must have low values as possible as because of it is a cost and to protect environment.
- Maximum stitch length: As a fabric is sewed small stitch length may be stronger but it may tear fabric. For this reason maximum stitch length is important for stylish stitches and temporary stitches. As Minimum stitch length is same in every machine, maximum stitch length is distinctive. Millimeter is selected as unit of stitch length.

In this paper, MOORA method and TOPSIS method were used for sewing machine selection in apparel sector.

2.1. MOORA METHOD

MOORA method is developed by Brauers and Zavadskas in 2006 (9). In Contrast to MOORA is a new method; its usage is increased rather in time. It is used for utility concept and material selection (10), performance evaluation in real estate sector (11) and contractor selection (12), design selection (4),(13), robot selection (14),(15), personnel selection (16), quality control (17), dynamic scheduling in production systems (18), location selection (19), firm selection (20) and healthcare waste management (21) etc. subjects in literature.

MOORA method's steps as below (4):

Step 1. Decision matrix which shows values of different alternatives for different objectives is created.

$$X = \begin{bmatrix} x_{11} & \ldots & x_{1j} & \ldots & x_{1n} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ x_{i1} & \ldots & x_{ij} & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ x_{m1} & \ldots & \ldots & \ldots & x_{mn} \end{bmatrix} \quad (2.1)$$

In this matrix x_{ij} shows value of alternative *i* according to objective or criteria *j* . *m* is number of alternatives and n is number of objective or criteria.

Step 2. Due to differences in criteria values of measurements have different units. In this situation it is too hard comment on these values by looking that. To achieve this problem normalization is required so that values of measurements transform dimensionless numbers. These dimensionless numbers are in [0, 1] interval so that commenting is very easy. Normalized values are showed with x_{ij}^* .

$$x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}} \quad (2.2)$$

According to Eq. (2.2) normalized value is obtained dividing alternative's value by squared root of sum of alternative's squares.

MOORA method has two different components: ratio system and reference point approach.

Step 3. According to ratio system ranking value is as below.

$$y_i^* = \sum_{i=1}^{g} x_{ij}^* - \sum_{i=g+1}^{n} x_{ij}^* \quad (2.3)$$

In fact, Eq. (2.3) means difference with sum of to maximize criteria and sum of to minimize criteria. Attained y_i^* values are ranked and the alternative has biggest value is selected as best alternative.

Step 4. In reference point approach, reference point equals difference between maximal objective reference point and normalized value found in step 2. Maximal objective reference point is realistic and non-subjective approach. Selected reference point between the alternatives is shown with r_j and it means reference point of *j*th objective (criteria).

$$r_j - x_{ij}^* \quad (2.4)$$

Step 5. In this step, distance of values is calculated and attained results are written in matrix. After this matrix is subjected to Tchebyheff's min-max metric operation, ranking is made

$$\underset{j}{Min}\left\{\max_i (r_j - x_{ij}^*)\right\} \quad (2.5)$$

2.2. TOPSIS METHOD

TOPSIS method is a multi-criteria decision making method which was developed by Hwang and Yoon in 1981. Method states that the best alternative is the nearest to positive ideal solution and furthest to negative ideal solution (22). As positive ideal solution maximize benefit criteria and minimize cost criteria, negative ideal solution maximize cost criteria and minimize benefit criteria (23).

TOPSIS method is used for performance evaluation (24)(25), service quality analysis (26), layout planning (27), supply chain (28), product selection (29), vendor selection (30), weapon selection (22) and risk assessment (23) subject in literature.

Method's the first two calculation step is same with MOORA method. The rest steps as below (30).

Step 3. Normalized values are weighted multiplying with weight matrix (*w*) which shows importance values of alternatives.

$$w = \begin{bmatrix} w_1 & w_2 & \ldots & w_n \end{bmatrix} \quad (2.6)$$

$$v_{ij} = w_j x_{ij}^* \quad (2.7)$$

Step 4.Positive ideal solution (V^*) and negative ideal solution (V^-) is calculated with help of weighted matrix.

$$V^* = \{v_1^*, v_2^*, \ldots, v_n^*\} = \left\{(\max_i v_{ij} \middle| j \in J), (\min_i v_{ij} \middle| j \in J'\right\} \quad (2.8)$$

$$V^- = \{v_1^-, v_2^-, \ldots, v_n^-\} = \left\{(\min_i v_{ij} \middle| j \in J), (\max_i v_{ij} \middle| j \in J'\right\} \quad (2.9)$$

Hereby, *J* is set of benefit criteria and J' is set of cost criteria.

Step 5. After defining positive ideal solution and negative ideal solution, distance of alternatives to these solutions can be found as below.

$$D^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2} \quad (2.10)$$

$$D^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \quad (2.11)$$

Step 6. Each alternative's distance of ideal solution is calculated as below and ranked. The alternative which has nearest value to 1 is best alternative.

$$CC_i = \frac{D_i^-}{D_i^- + D_i^*} \tag{2.12}$$

3. APPLICATION

The data used in this paper for selecting sewing machine as below.

Table 2. Data for sewing machines

Machine	Speed (Max)	Price (Min)	Energy Consumption (Min)	Maximum Stitch Length (Max)
SM1	5000	2656.76	450	4.2
SM2	5000	2350.48	500	4.0
SM3	5000	2717.69	450	4.0
SM4	4500	2229.30	400	4.0
SM5	4500	2684.88	400	5.0
SM6	5500	3729.00	400	4.5

Using Eq. (2.2) normalized matrix as below.

Table 3. Normalized data

Machine	Speed	Price	Energy Consumption	Maximum Stitch Length
SM1	0.4142	0.3915	0.4224	0.3988
SM2	0.4142	0.3464	0.4693	0.3799
SM3	0.4142	0.4005	0.4224	0.3799
SM4	0.3727	0.3285	0.3755	0.3799
SM5	0.3727	0.3956	0.3755	0.4748
SM6	0.4556	0.5495	0.3755	0.4273

Ranking values of MOORA Method's ratio system and ranking result as below.

Table 4. Ranking values of ratio system

Machine	Speed	Price	Energy Consumption	Maximum Stitch Length	Y_i	Y_i^*	Ranking
SM1	0.4142	0.3915	0.4224	0.3988	-0.0009	0.9227	3
SM2	0.4142	0.3464	0.4693	0.3799	-0.0216	0.9020	4
SM3	0.4142	0.4005	0.4224	0.3799	-0.0288	0.8948	5
SM4	0.3727	0.3285	0.3755	0.3799	0.0486	0.9722	2
SM5	0.3727	0.3956	0.3755	0.4748	0.0764	1.0000	1
SM6	0.4556	0.5495	0.3755	0.4273	-0.0421	0.8815	6
					0.9236		

When values of Table 4 analyzed, it is seen that ranking values have both negative and positive values. This situation may cause ranking for decision makers, to solve this problem added value to the biggest value which is 0.9236 added to other values. According to this the best three alternatives are SM5, SM4 and SM1. Ranking values are calculated by reference point approach as below.

Table 5. Values of reference point approach

Machine	Speed	Price	Energy Consumption	Maximum Stitch Length	Max	Ranking
SM1	0.0414	0.0630	0.0469	0.0760	0.0760	1
SM2	0.0414	0.0179	0.0938	0.0949	0.0949	3
SM3	0.0414	0.0720	0.0469	0.0949	0.0949	3
SM4	0.0829	0.0000	0.0000	0.0949	0.0949	3
SM5	0.0829	0.0671	0.0000	0.0000	0.0829	2
SM6	0.0000	0.2210	0.0000	0.0475	0.2210	6
Max/min	0.4556	0.3285	0.3755	0.4748		

Table 5 shows that the best three alternatives are SM1, SM5 and SM4. Calculations based on Eq. (2.5) SM2, SM3 and SM4 give same results so that decision makers may be indifferent between these alternatives and 3rd rank is given them.

Weight matrix will be as below when criteria has same importance.

Table 6. Weights

Speed	Price	Energy Consumption	Maximum Stitch Length
0.25	0.25	0.25	0.25

Weighted decision matrix as below.

Table 7. Weighted decision matrix

Machine	Speed	Price	Energy Consumption	Maximum Stitch Length
SM1	0.1036	0.0979	0.1056	0.0997
SM2	0.1036	0.0866	0.1173	0.0950
SM3	0.1036	0.1001	0.1056	0.0950
SM4	0.0932	0.0821	0.0939	0.0950
SM5	0.0932	0.0989	0.0939	0.1187
SM6	0.1139	0.1374	0.0939	0.1068

Positive ideal solution and negative ideal solution are as below.

Table 8. Solution values

	Speed	Price	Energy Consumption	Maximum Stitch Length
V^*	0.1139	0.0821	0.0939	0.1187
V^-	0.0932	0.1374	0.1173	0.0950

Distance of alternatives to positive and negative ideal solutions are as below.

Table 9. Distances of alternatives

Machine	D^*	D^-
SM1	0.0292	0.0428
SM2	0.0352	0.0518
SM3	0.0336	0.0404
SM4	0.0315	0.0600
SM5	0.0267	0.0509
SM6	0.0565	0.0335

Ranking values which are obtained from Table 9 are as below.

Table 10. Ranking of alternatives with TOPSIS

Decision	CC	Rank
SM1	0.5940	4
SM2	0.5954	3
SM3	0.5457	5
SM4	0.6558	2
SM5	0.6563	1
SM6	0.3719	6

The best three alternatives according to TOPSIS are SM5, SM4 and SM2.

4. RESULTS

Businesses can achieve their main objective by keeping their revenues at maximum level and their costs at minimum levels. To do this in apparel sector machine selection requires purchasing optimal sewing machine. For this reason to select optimal machine, calculations are made using MOORA and TOPSIS methods. Attained three results (SM5, SM4, SM1), (SM1, SM5, SM4) and (SM5, SM4, SM2) could be said that consistent. According to these results SM5 becomes prominent so that 5^{th} alternative may be purchased as optimal alternative.

When used multi-criteria decision making methods compared, MOORA method is seen too easy and needs less calculations according to TOPSIS method. So that it is anticipated that for all that MOORA is a new method it will be larger application area itself in future.

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