Integration of multi-criteria decision making method for performance evaluation: An application in the apparel business

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TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and AHP (Analytic Hierarchy Process) are multi-criteria decision-making tools commonly seen in studies in recent years. The aim of this study is to evaluate performance of medium-sized apparel company considering indicators that affect the productivity. In accordance with this purpose AHP and TOPSIS methods are combined together. Weighting of the criteria is defined by the AHP (pairwise comparisons) and ranking of the alternatives according to the weighted criteria is evaluated TOPSIS method. This study is thought to be useful for the producers in terms of providing feedback and analysis.
***Key words**: Multi-Criteria Decision Making, TOPSIS, AHP, Apparel Sector, Performance Evaluation*

1. Introduction and literature review

Business performance is the result of interactions and joint efforts of all components such as machines, employees, management, assets and environment. Making proper work in the performance subject depends on addressing this issue within the scope of management process [1]. With the help of performance evaluation following questions are trying to be answered: "Where we are ?, Where we could be ? How much good we are? or Where we should be ?". Finding answers to these questions mean determining the current status of the company, comparing the current situation with the planned and making decisions for the future. In order to perform all these issues, managers will need some indicators. Through prepared indicators for areas of importance to business, try to give answers to the three issues mentioned by performance measurement [2]. If performance values don't evaluate and benefit from the valuation results, it would be impossible to achieve the healthy judgment [3]. Textile and apparel sector is one of the most advanced branches of industry and directly affects the economy in Turkey. Assessing the relative performance within the sector and identifying the companies that need to be taken as a reference are required. At this point in order to achieve the desired level of output, efficiency and productivity analysis are very important management tool that should be utilized [4-6]. Various approaches and methods have been developed for performance evaluation purposes. Among these methods according to the structure of the organization, their needs, goals, and sometimes with a choice of several possible methods depending on the nature of the employees are able to synthesize a combination of performance evaluation [7].

Analytical modelings for performance evaluation vary from simple weighting techniques to complex mathematical programming approach. Related to this subject, there are some multi-criteria mathematical programming and other advanced methodologies [8]. It can be seen that the multi-criteria decision making techniques commonly used for this purpose.

There has been a lot of studies regarding the combination of multi-criteria decision making methods in order to performance evaluation for different sectors. Choosing the most suitable supplier business [9] and assessing services performance of the commercial bank, Analytic Hierarchy Process (AHP) and TOPSIS was conducted using a combination of methods [10]. To choose the most suitable enterprise resource planning software for companies in the manufacturing sector fuzzy AHP and fuzzy MOORA [11], eliminating the hesitation of consumers regarding credit cards, to set an example relating how to make selection, AHP and ELECTRE [12], determining the appropriate marketing strategy AHP and VIKOR methods were used together [13]. As seen in previous studies multiple-criteria decision making methods for the performance evaluation has been used together quite extensively.

In this study, after determining the related criteria AHP and TOPSIS methods used together in order to evaluate performance of a company operating in apparel business and the results are evaluated.

2. Materials and methods

2.1. Purpose of the study

This study was conducted with data recorded in a medium-sized apparel company. Company has undergone some structural changes by taking some professional support and started to monitor and record the values related with productivity. Objective of this study is to analyze the effect of these changes on the results on yearly basis by using scientific methods and to make performance evaluation to see whether there is a progress or not. Since the results point out the ongoing performance values, they provide crucial data and are expected to be guidelines to any long-term plans.

2.2. Material

An apparel company located in İzmir was selected for implementation. The company in question produced goods from knitted fabrics since 1993. The production was converted to exportation in 2002 carrying out both export and manufacture with high end machinery. Production quantities (garment in year) of the company for the three years (2012 - 2014) are shown in Fig.1.

The company has been recording data regularly and monitoring production process and performance with various analyses since 2012. Thus, after consulting with firm executives, activity records in years 2012, 2013 and 2014 were evaluated. Among data, parameters directly affecting performance were taken into account and the data to be analyzed were defined. Defect types to be used as a first matrix and related classifications are displayed below. Eight defect types were determined after consulting the quality control department and they are defined below.

Fabric defect: Defined as color difference among products, irregular thread and fabric surface, touching and drape out of tolerance.

Repair: Listed as stitch defect, faulty seam, wrong label, asymmetrical pocket or pocket flap, accessories with malfunction.

Fault: Deployment of hole or tear on fabric or lining, permanent stains, unrecoverable creases.

Stain-Dirt: Stain or dirt on the surface of the product.

Thread-Leveling: Longer than 1,5 cm thread on the product, unregulated products.

Major Defect: Defects that cause the product to fail its intended use and shorten its life during usage.

Minor Defect: Defects that cause customer complaints and leads the customer to prefer another product without the same defect.

Critical Defect: Defects influencing the health of the end user or having inconvenient legal issues.

Data obtained from studies for productivity in the firm has created the criteria of the second matrix. They were selected as efficiency of production line, rate of production line repair, average quality performance of worker and production amount per worker. By using these values, required rates were calculated annually for the stated years with the help of below formulas.

Tab.1 Symbols for related criteria

Criteria	Symbol	Criteria	Symbol
Fabric defect rate	C1	Minor defect rate	C7
Repair rate	C2	Critical defect rate	C8
Fault rate	C3	Efficiency of production line	C9
Stain-Dirt rate	C4	Rate of production line repair	C10
Thread-Leveling rate	C5	Average quality performance of worker	C11
Major defect rate	C6	Production amount per worker	C12

$$\text{Efficiency of production line} = \frac{\textit{Daily production amount} \times \textit{cycle time}}{\textit{Daily working time} \times \textit{number of workers in the line}} \times 100 \quad (1)$$

$$\text{Rate of production line repair} = \frac{\textit{Total defect amount in the line}}{\textit{Total controlled production amount}} \quad (2)$$

$$\text{Average quality performance of worker} = \frac{\textit{Daily defective production amount}}{\textit{Daily total controlled amount}} \quad (3)$$

$$\text{Production amount per worker} = \frac{\textit{Number of employee}}{\textit{Total production amount}} \quad (4)$$

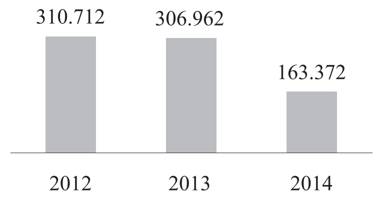

Fig.1 Annual garment production

Among these criteria, it is expected that rate of eight defect types and rate of production line repair should be low and the efficiency of production line, average quality performance of worker and production amount per worker are expected to be high. Defect Type Rates and Related Efficiency Rates which were explained above were used in matrices and were symbolized in Tab.1.

2.3. Methodology

AHP Method

AHP is developed by Thomas L. Saaty in 1971 and formed by many discrete concepts and techniques. They may be listed as hierarchic configuration of complexity, pairwise comparison, use of eigen vector in derivation of weights and measurement of consistency [14].

To begin with, decision hierarchy is created for objective, criterion, sub-criterion and alternatives. In order to determine the importance levels of criteria and sub-criteria between themselves, pairwise comparison matrix is created. For decision making criteria matrix and alternative matrix, criteria and alternatives are compared by using a scale of 1-9 scoring developed by Saaty as pairwise comparison [15].

An eigenvector with nx1 dimension of the concerned matrix which shows the importance of an element with respect to other elements and priority vector found by using the equation 5 as shown below and column vector as equation 6 are calculated.

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \qquad (5)$$

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n} \qquad (6)$$

Consistency rate (*CR*) for the comparisons is calculated (equations 7-10) and it is required that this rate should be less than 0,10. The value greater than 0,10 implies an inconsistency on the part of the decision-maker's judgements.

$$E_i = \frac{d_i}{w_i} \qquad (7)$$

$$\lambda = \frac{\sum_{i=1}^{n} E_i}{n} \qquad (8)$$

$$CI = \frac{\lambda - n}{n-1} \qquad (9)$$

$$CR = \frac{CI}{RI} \qquad (10)$$

In order to reach a general result of hierarchic structure, *DW* decision matrix is obtained with *m×n* dimension formed by superiority of *n* criteria as column vectors, each having *m×1* dimension. Multiplying this by *W* superiority vector, result vector *R* is reached.

TOPSIS Method

TOPSIS method was introduced for the first time by Yoon and Hwang (1981) [16]. The main idea of the method is to obtain the solution which is closest distance from the positive ideal solution and farthest from the negative ideal solution. Process steps of the TOPSIS methods are presented below [17].

Step 1. Construct initial decision matrix (A)

Alternative *i, i=1,2,...,m* horizontally and criteria *j, j=1,2,...,n* vertically are placed in the decision matrix. It is created by the decision makers and shown in the eq. (11).

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix} \qquad (11)$$

Step 2. Construct normalized decision matrix (R)

There are some other techniques to perform normalization process. Vector normalization is a method frequently used. Vector normalization for the normalized decision matrix is given in the eq. (12).

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \qquad (12)$$

R matrix is expressed as Eq. (13).

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix} \qquad (13)$$

Step. 3 Construct weighted normalized decision matrix (V)

Primarily weight values (w_i) related to the evaluation criteria are determined ($\Sigma_{i=1}^{n} w_i = 1$). To construct the weighted normalized decision matrix, the normalized decision matrix are multiplied by its associated weights. The structure of matrix *V* is given in eq. (14).

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \dots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \dots & w_n r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1 r_{m1} & w_2 r_{m2} & \dots & w_n r_{mn} \end{bmatrix} \qquad (14)$$

Step 4. Determine the positive ideal (A^*) and negative ideal (A^-) solution

The largest value of the column for the ideal solution set is selected (the smallest one if the related criterion is minimization oriented). Finding positive ideal solution set is shown in eq. (15).

$$A^* = \{(\max_i v_{ij} \mid j \in J), (\min_i v_{ij} \mid j \in J')\} \qquad (15)$$

$$A^* = \{v_1^*, v_2^* \dots v_n^*\} \qquad (16)$$

For the negatif ideal solution set, the smallest values of the column (the largest one if the related criterion is maximization oriented) are found. Negative ideal solution set is given in eq. (17).

$$A^{-} = \{(\min_{i} v_{ij} \mid j \in J), (\max_{i} v_{ij} \mid j \in J')\} \quad (17)$$

$$A^{-} = \{v_1^{-}, v_2^{-} \ldots v_n^{-}\} \quad (18)$$

Step 5. Calculation of the separation measure to the ideal and negative ideal solution

Euclidian distance are used to determine the separation of each alternative from the ideal solution and negative ideal solution. The calculation of (S_i^*) and (S_i^-) are given in eq. (19) and (20).

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2} \quad (19)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \quad (20)$$

Step 6. Calculation of the relative closeness to the ideal solution

The relative closeness to the ideal solution (C_i^*) which is found by using the distance measures calculated in previous step. Calculation of the relative closeness to the ideal solution are presented in eq. (21).

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \quad (21)$$

The value of C_i^* is between $0 \leq C_i^* \leq 1$ and $C_i^* = 1$ shows the absolute closeness of the corresponding alternative to the ideal solution, in the same sense $C_i^* = 0$ shows the absolute closeness of the corresponding alternative to the negative ideal solution.

3. Application

Application part of the study consists of three basic steps: determination of selection criteria, configuration of selection criteria and ranking of the alternatives. After determining criteria, AHP method was referred for providing the contribution of each evaluation criteria to the objective when there are many factors for evaluation. Then steps of TOPSIS were taken to obtain ranking, and weighting values were also used to reach a performance assessment. With these integrated approach, positive advantages of both methods are used for evaluation of results as shown in Fig.2.

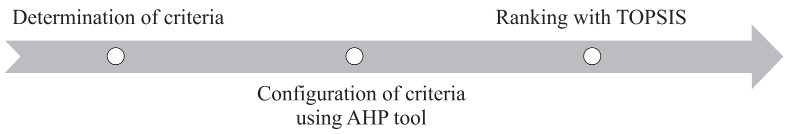

Fig.2 Implementation of AHP-TOPSIS integration

Tab.2 Pairwise comparison matrix for defect types

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	4	3	3	5	1/3	1/4	1/5
C2	1/4	1	1/3	1/3	3	1/5	1/6	1/8
C3	1/3	3	1	1	5	1/4	1/5	1/7
C4	1/3	3	1	1	5	1/4	1/5	1/7
C5	1/5	1/3	1/5	1/5	1	1/6	1/7	1/9
C6	3	5	4	4	6	1	1/3	1/4
C7	4	6	5	5	7	3	1	1/3
C8	5	8	7	7	9	4	3	1

Tab.3 Resulting weights for the criteria of defect rates

Priority
9 %
3 %
5 %
5 %
2 %
15 %
23 %
38 %
CR: 0,07

Tab.4 Resulting weights for the critera of related efficiency values

Priority
61 %
12 %
23 %
4 %
CR: 0,08

Determination of criteria weights with AHP: Microsoft Excel 2010 is utilized for the steps of the methods used in this study. Application of AHP method is used primarily to determine the importance weight of related criteria. Pairwise comparisons between criteria were created by using scale of relative importance in interviews according to experience and acquisition of authority in the enterprise (see Tab.2).

After getting normalized matrix, priority vectors were found by using the averages of each row. Consistency Ratio (*CR*) which is required to be less than 0,1 was calculated as 0,07. Weight values of defect types specified are shown in Tab.3 respectively. According to importance levels of criteria to be used in the first matrix,

Tab.5 Initial decision matrix of the defect rates

Year/ Criteria	C1	C2	C3	C4	C5	C6	C7	C8
2012	0,06 %	2 %	0,7 %	0,02 %	1,5 %	1,08 %	2,72 %	0,001 %
2013	0,5 %	2,4 %	0,5 %	2,2 %	3,5 %	1,7 %	2,5 %	0,012 %
2014	0,25 %	4 %	0,01 %	2 %	3,5 %	0,8 %	1,8 %	0,001 %

Tab.6 Initial decision matrix of related efficiency values

Year/Criteria	C9	C10	C11	C12
2012	61,20 %	5,20 %	92,50 %	4376
2013	62,30 %	4,20 %	93,20 %	3410
2014	70 %	3,60 %	95,70 %	2207

Tab.7 Performance values of both situations (C_i^*)

	C_i^* Values	
	Defect types	Efficiency values
2012	0,27	0,29
2013	0,35	0,33
2014	0,73	0,71

C8 (Critical defect rate) has the highest priority with 38 percent.

The same applications are performed for the efficiency criteria (C9, C10, C11, C12) and their weight values are also seen in Tab.4 respectively. According to the results, C9 (Efficiency of production line) has the highest priority with 61 percent. *CR* value is also determined as 0,08.

Obtaining ranking with TOPSIS: After criteria weights of the two cases were determined, steps of TOPSIS method were applied to evaluate the annual defect rate and efficiency parameters accumulated in three years. Initial decision matrices making information were taken from the company are given in Tab.5 and 6 respectively.

After implementation of TOPSIS method steps, proximity (C_i^*) values according to calculated ideal solution in order to determine the year with the highest performance are shown in Tab.7.

Both defect types and productivity values have tendency to increase towards the year 2014 as shown in Fig.3.

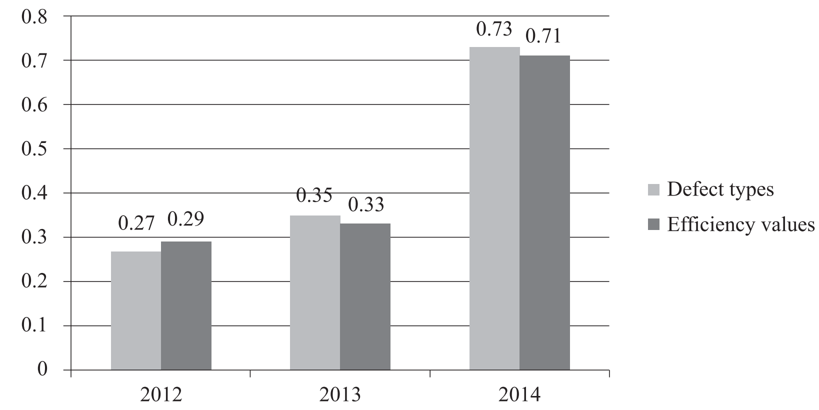

Fig. 3 Yearly performance values

4. Conclusion and general evaluation

In this study performance ratings of the apparel firm according to the specified performance criteria are determined with in TOPSIS and AHP combination. Primarily, 12 different criteria are established, based on these criteria two different cases are created and success ranking for the years from 2012 to 2014 is determined. According to the performance ratings for these two cases, year 2014 has been showed the best performance and the years of 2013 and 2012 are in the second and third rank respectively.

Different models are produced each year and these models show changes seasonally. Each model has different difficulty levels, require different process and labor. This situation is likely to result in favor of 2014. That firm has been keeping the records of the information about the production, analyzing them and efforts to increase the efficiency since the year of 2012 can be evaluated as another issue about the reality of the result. Looking at this subject from a different standpoint, since performance criteria used in both cases are related with each other efficiency values and defect rates give parallel results. When examined the general result by years, company has a nonlinear success rate. This situation could result from some internal and external reasons. Cause of increase especially the years show high and low performance values should be analyzed.

No matter what the reasons are, company should take into consideration more objective criteria for their future decisions. TOPSIS and AHP as a multi-criteria decision making tools help them taking a firm action and create new vision with regard to long-term plan. Defect rates and some efficiency parameters are used in this subject, for extensive evaluation related data directly or indirectly effect the performance of the firm must be recorded. It is possible that another decision making tools can be implemented to measure the efficiency and evaluate the performance for further studies.

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