(REFEREED RESEARCH)

MEASUREMENT OF SUSTAINABILITY PERFORMANCE IN TEXTILE INDUSTRY BY USING A MULTI-CRITERIA DECISION MAKING METHOD

ÇOK KRİTERLİ KARAR VERME METODU KULLANILARAK TEKSTİL ENDÜSTRİSİNDE SÜRDÜRÜLEBİLİRLİK PERFORMANSI ÖLÇÜMÜ

Eda ACAR, Merve KILIÇ, Mücella GÜNER

Ege University, Department of Textile Engineering, İzmir, Turkey

Received: 02.07.2014 Accepted: 18.11.2014

ABSTRACT

The concept of sustainability has been well fitted to the aim of industrial applications for managing limited resources and producing with minimum harm to environment. From this aspect, importance of sustainable manufacturing and monitoring environmental impact has been increased rapidly for both researchers and decision makers. Therefore, there is a need to measure "sustainability" with its three aspects such as environmental, economic and social dimensions. Multi-criteria decision making (MCDM) methods provide a useful framework for measuring and the evaluation of sustainability performance. This paper presents a study based on the data related with environmental factors for assessing a company's production performance from the aspect of sustainability by concentrating on a corporate group in textile industry. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is adopted and data from annual reports of Inditex Group is used while assessing sustainability performance.

Keywords: Sustainability, Sustainability Measurement, Multi-Criteria Decision Making, TOPSIS Method, Textile Industry.

ÖZET

Sürdürülebilirlik, endüstriyel uygulamaların kıt kaynakları yönetmek ve çevreye en az hasar verecek üretimi hedefleyen yapısıyla uyumlu olan bir konsepttir. Bu açıdan yaklaşıldığında, sürdürülebilir imalat ve çevresel etkinin izlenmesi, araştırmacı ve endüstrideki karar vericiler açısından önem kazanmaktadır. Sürdürülebilirliğin çevresel, ekonomik ve sosyal olmak üzere üç boyutu bulunmaktadır ve bu üç boyutun değerlendirilmesi bir ihtiyaç haline gelmektedir. Çok kriterli karar verme yöntemleri ise sürdürülebilirlik performansını ölçme ve değerlendirmede kullanışlı bir çerçeve sunmaktadır. Bu makale, tekstil sektöründeki bir kurumsal şirketin üretim faaliyetlerinin çevresel faktörler baz alınarak performans değerlendirmesini sürdürülebilirlik açısından ele almaktadır. Bu çalışmada şirketin yıllık raporlarından derlenen veriler TOPSIS yöntemiyle ele alınarak şirketin sürdürülebilirlik performansı değerlendirilmiştir.

Anahtar Kelimeler: Sürdürülebilirlik, Sürdürülebilirlik Değerlendirmesi, Çok Kriterli Karar Verme, TOPSIS Yöntemi, Tekstil Endüstrisi.

Corresponding Author: Eda Acar, eda.acar@ege.edu.tr, Tel: +90 02323111919

1. INTRODUCTION

Starting with the industrial revolution, mass production is caused to resources have been consumed unconsciously, and therefore discharged wastes after the manufacturing process have damaged to the ecological structure dramatically. In this direction sustainability which is one of the most important senses of obligation has gained value in terms of preservation and transmission of the resources to future generations. The term of sustainability is firstly defined by Brundtland Commission's of United Nations in the report of World Commission on Environment and Development (WCED) as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs (1). Sustainable development is the development that is likely to achieve

lasting satisfaction of human needs and improvement of the quality of life under the condition that ecosystems and/or species are utilized at levels and in ways that allow them to keep renewing themselves (2).

While importance of the sustainability has been increased rapidly, companies become more willing to adopt this concept not only for environmental concerns but also using the resources efficiently to survive in competitive market and succeed in business financially. Therefore it has become necessary to measure and evaluate sustainability for a company. However, sustainability is considered an abstract issue which is hard to measure. Hence many researchers have been focused on developing indicators to monitor and assess to environmental impacts of manufacturing activities. Since the sustainability is a concept that includes conflicting criteria and decision points, MCDM methods are useful tool to assess performance in many cases.

In this point MCDM methods support decision makers when there are multiple objectives in the presence of multiple criteria (3). These methods provide a preference order for the problem and the aim is not optimizing the solution. TOPSIS is the one of these methods adopted the principle of closeness of the decision points to the ideal solution. TOPSIS is a practical method by assessing the sustainability performance of a company. This method is preferable when considering the application convenience and simplicity for identifying the suitable alternative quickly.

Similarly to other industries, sustainable manufacturing is hot topic in textile industry. Since the textile industry is one of the industries that consume a lot of water, air, chemicals and energy, it contributes environmental problems almost in every step of the production from raw material to the finished good (4).

Pressure on textile companies to accord with the environmental factors has been increased. Hence, companies consider as an obligatory to make public their accordance of the economic, social and environmental factors (5).

In this study, yearly sustainability reports of the company are analyzed and data available for computational application is derived in order to perform TOPSIS method. Study also has considered two cases for analyzing the sustainability performance of company in related years from 2008 to 2012.

2. LITERATURE REVIEW

Literature review clearly shows that TOPSIS method is one of the most and widely applied method to asses and reliably measure sustainability in almost every sector. A multiple criteria nature of the sustainable supply chain measurement problem is considered in a study. Multi-criteria framework based on fuzzy entropy and fuzzy multi-attribute utility (FMAUT) is proposed in order to evaluate and compare the company performances in terms of sustainable supply chain (6). Another study aimed to assess the corporate sustainability performance using “compromise programing (CP)”, one of the MCDM methods. Data were acquired from Henkel Company’s annual reports. Environmental and social aspects of Henkel’s corporate sustainability are compared by years using the data acquired from Henkel Company’s annual reports, and in conclusion, using CP model to evaluate corporate sustainability is proposed (7). Analytical hierarchy process (AHP) is used to assist in evaluating the impact of an organization's sustainability performance and presented a conceptual decision model for a steel company in India (8). For the sustainability of the paper industry in Europe, compromise programming has been evaluated for this purpose (9). For selecting sustainability transportation systems under partial or incomplete information (uncertainty) a multicriteria decision making approach is proposed (10). The data taken from the annual sustainability reports of British Petroleum (BP) was used for sustainability assessment in another study. The sustainability of BP between 2003-2006 was assessed and evaluated by Entropy, ELECTRE and TOPSIS techniques (11). For the sustainable flooring system in the city of Tehran, AHP is used as a multi-criteria decision making technique, integration of AHP and Life Cycle Analysis provides a framework for robust decision making that is consistent with sustainable construction practices (12). AHP and TOPSIS are integrated together for alternative screening and ranking so as to help decision makers in a Portuguese solid waste management system (13). The Complex Proportional Assessment (COPRAS) method of multi-criteria decision making is preferred and applied to three residential areas to assess the affordability of different housing locations in a sustainable manner using a MCDM method (14). It can be predicted from the previous studies that evaluating the subject of sustainability in almost every industry has been received wide literature coverage.

3. MATERIAL AND METHOD

Sustainability performance by years of Inditex Group has been investigated in this study. The purpose is to assess environmental sustainability performance based on sustainability indicators which are derived from data provided by annual reports of Inditex Group by using TOPSIS method. This study also gives a chance to evaluate sustainability performance between different companies in the same industry.

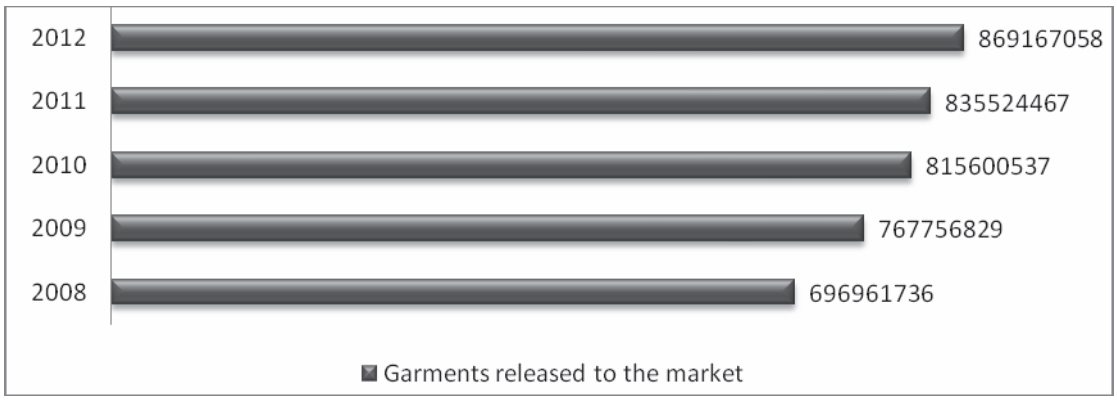
3.1 MATERIAL

Inditex group is a corporate company that established in 1985 and performs in textile industry. This company reserves several firms which have different fashion brands in its organization. As of 2012 there are over 5693 store and 100.000 employees belong to this company. Data in sustainability report of the Inditex group between the years 2008 and 2012 are used as a material in this study.

Decision points are the years from 2008 to 2012 and decision criteria are indicators labeled from I_1 to I_{25} and explained in the Table 1. Each indicator is in the form of ratio and calculated by dividing the related output given as absolute data from sustainability report into amount of garments released to the market in associated year. For this calculation step the yearly amount of garments are shown in Graph 1. Data provided by Inditex’s sustainability report is converted to essential units for calculation convenience.

Table 1. Indicators and their units (15)

			Unit of measure
Resource Consumption and Generation	I_1	Overall energy consumption ratio	MJ/garment
	I_2	Overall natural gas consumption ratio	MJ/garment
	I_3	Overall diesel consumption ratio	MJ/garment
	I_4	Electricity consumption ratio in head offices and factories	kWh/garment
	I_5	Renewable energy generation and tri-generation ratio	kWh/garment
	I_6	Water consumption ratio	m^3/garment
Greenhouse Gas Emissions	I_7	Greenhouse gas emissions ratio	g CO_2eq/ garment
	I_8	Greenhouse gas emissions ratio from transport	g CO_2eq/garment
	I_9	NO_x emissions ratio	g/garment
	I_{10}	CO emissions ratio	g/garment
	I_{11}	SO_2 emissions ratio	g/garment
General Types of Waste and Contaminators Ratio	I_{12}	Hazardous waste ratio	g/garment
	I_{13}	Wood wastes ratio	g/garment
	I_{14}	Plastic wastes ratio	g/garment
	I_{15}	Cardboard and paper wastes ratio	g/garment
	I_{16}	Textile wastes ratio	g/garment
Specific Types of Hazardous Waste Ratio	I_{17}	Battery wastes ratio	g/garment
	I_{18}	Electronic wastes ratio	g/garment
	I_{19}	Fluorescents waste ratio	g/garment
	I_{20}	Oil filters waste ratio	g/garment
	I_{21}	Contaminated metal packaging wastes ratio	g/garment
	I_{22}	Used mineral oil wastes ratio	g/garment
	I_{23}	Contaminated absorbents waste ratio	g/garment
	I_{24}	Paint wastes ratio	g/garment
	I_{25}	Contaminated plastic packaging wastes ratio	g/garment



Graph 1. Garments released to the market through all the stores, both owned and franchised (15)

3.2 TOPSIS METHOD AND APPLICATION STEPS

TOPSIS is the short term which represents Technique for Order Preference by Similarity to Ideal Solution and it's developed by Hwang and Yoon in 1981 (16). TOPSIS method based on the idea that selected alternative should be at the shortest distance from the positive ideal solution where the positive ideal solution represents the best criteria values. And also it should be at the farthest point from the negative ideal solution where the negative ideal solution represents the worst criteria values amongst other alternatives. TOPSIS can be summarized in six steps (17).

1. In first step, evaluation matrix is built by listing alternative horizontally and criterions vertically and shown in Equation (1).

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

2. Second step consists of dividing each center values by the norm of the total outcome vector in order to non-dimensionalize the center values in the evaluation matrix. These are given by the Equation (2) and Equation (3).

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

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix} \quad (3)$$

3. The normalized decision matrix are multiplied by its associated weights (w_i) $\left(\sum_{i=1}^{n} w_i = 1\right)$. The structure of matrix Y is given in Equation (4).

4. The fourth step shown in equation (5) and equation (6) respectively, consist of building positive and negative ideal solutions to compare the alternatives with each other.

5. After determining the positive and negative ideal solutions, the separation of each matrix value from the ideals are measured as Euclidean distances in the fifth step by using the equation (7) and equation (8).

6. At the sixth step, these distances are transformed into a single metric called relative closeness to the ideal solution with the help of equation (9).

C_i^* is calculated between $0 \le C_i^* \le 1$. *Ci* = 1 shows the absolute closeness of the corresponding alternative to the ideal solution, in the same sense *Ci* = 0 shows the absolute closeness of the corresponding alternative to the negative ideal solution.

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \dots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \dots & w_n r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1 r_{m1} & w_2 r_{m2} & \dots & w_n r_{mn} \end{bmatrix} \quad (4)$$

4. APPLICATION AND FINDINGS

In the first case indicators from I_1 to I_{25} represented in Table 1 are used in TOPSIS method in order to interpret the company's environmental sustainability performance based on the years between 2008 and 2012. Data gathered from annual reports of the company and years from 2008 to 2012 are specified as decision points as it is previously mentioned. Second study considers only the indicators of the specific types of hazardous waste for analyzing the performance of company in related years from 2008 to 2012. The initial decision matrix of the first case is represented in Table 2, Table 3 and Table 4. These tables include indicators from I_1 to I_8, I_9 to I_{17} and I_{18} to I_{25} respectively.

$$A^* = \left\{ \left(\max_i v_{ij} \,\middle|\, j \in J\right), \left(\min_i v_{ij} \,\middle|\, j \in J'\right) \right\} \qquad A^* = \left\{v_1^*, v_2^*, \dots, v_n^*\right\} \quad (5)$$

$$A^- = \left\{ \left(\min_i v_{ij} \,\middle|\, j \in J\right), \left(\max_i v_{ij} \,\middle|\, j \in J'\right) \right\} \qquad A^- = \left\{v_1^-, v_2^-, \dots, v_n^-\right\} \quad (6)$$

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2} \quad (7) \qquad S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \quad (8)$$

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \quad (9)$$

Table 2. Initial Decision Matrix (I_1 - I_8)

	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8
2008	4.4679	0.5885	0.0603	0.0434	0.0465	0.0004	454.35	357.025
2009	4.2695	0.5398	0.0346	0.0337	0.0384	0.0004	436.63	323.046
2010	3.9664	0.4775	0.0224	0.0326	0.0350	0.0004	407.64	354.868
2011	4.0525	0.4446	0.0169	0.0287	0.0334	0.0009	374.66	397.471
2012	4.6136	0.4818	0.0142	0.0304	0.0306	0.0011	361.95	458.091

Table 3. Initial Decision Matrix (I_9 - I_{17})

	I_9	I_{10}	I_{11}	I_{12}	I_{13}	I_{14}	I_{15}	I_{16}	I_{17}
2008	0.07	0.081	0.003	0.0654	1.3867	0.5279	9.9388	1.7277	0.0012
2009	0.02	0.039	0.004	0.0301	1.0705	0.5171	8.1379	1.1789	0.0018
2010	0.03	0.028	0.003	0.0204	1.8268	0.7830	8.3278	1.1889	0.0009
2011	0.03	0.034	0.004	0.0579	1.7018	0.4952	8.3363	0.8494	0.0005
2012	0.03	0.025	0.004	0.0391	1.9482	0.3126	7.9670	0.6943	0.0036

Table 4. Initial Decision Matrix (I_{18} - I_{25})

	I_{18}	I_{19}	I_{20}	I_{21}	I_{22}	I_{23}	I_{24}	I_{25}
2008	0.0152	0.0025	0.0012	0.0005	0.0081	0.0028	0.0002	0.0022
2009	0.0061	0.0014	0.0005	0.0008	0.0024	0.0019	0.0004	0.0031
2010	0.0025	0.0019	0.0004	0.0003	0.0033	0.0022	0.0003	0.0009
2011	0.0126	0.0056	0.0014	0.0005	0.0188	0.0021	0.0005	0.0030
2012	0.0048	0.0008	0.0005	0.0004	0.0076	0.0028	0.0001	0.0012

In order to make the years comparable with each other, indicators are determined based on the production outputs in terms of material consumption, waste and greenhouse gases release. Production amounts are different in each year. Indicators are calculated by dividing the each data recorded in a year by the amount of garments released on the market in related year to find the values in the terms of a unit product of indicator. For instance, in order to obtain the initial decision matrix, data for overall energy consumption is given as in terms of terrajoule (TJ) in the report and related data from this section is converted into megajoule (MJ) then divided by garments released to the market.

As an example, overall diesel consumption value is given as 1005 in terms of tonne of oil equivalent (toe). Since 1 toe is equal to 41868 MJ, I_3 is calculated for 2008 as follows:

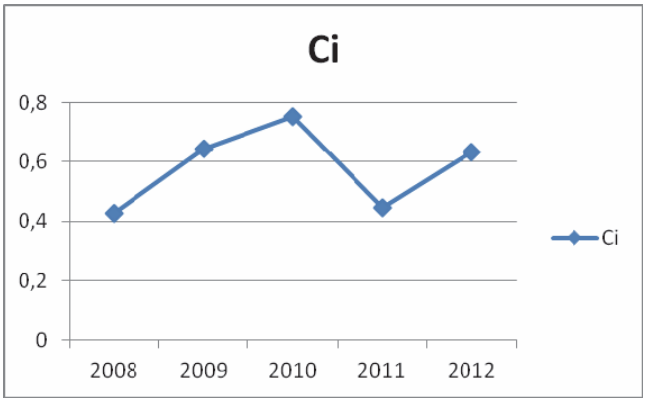
$$\frac{1005x41868}{696961736} = 0.0603 \text{ (MJ/garment)}$$

Weights for each indicator are assumed to be equal for both cases. After performing the TOPSIS method, the performance values of each year are shown in Table 5.

Table 5. Performance values due to years

	Years	C_i
C_1	2008	0.4255
C_2	2009	0.6439
C_3	2010	0.7553
C_4	2011	0.4479
C_5	2012	0.6352

Graph 2 shows trend of the sustainability performance according to years for the first case. The performance value is at the minimum level in 2008. It can be seen that there is a peak in the year of 2010 and also best performance based on the sustainability indicators are recorded in the year of 2010. In the year of 2011 the performance value has drastically fallen then started to increase in 2012 and reached to close level with the value calculated for the year 2009.



Graph 2. Performance values represent the years from 2008 to 2012

As a second study, the specific types of hazardous waste are analyzed and the related section includes indicators labeled from 17 to 25 which are already shown in Table 1. Table 6 also shows initial decision matrix of specific types of hazardous waste.

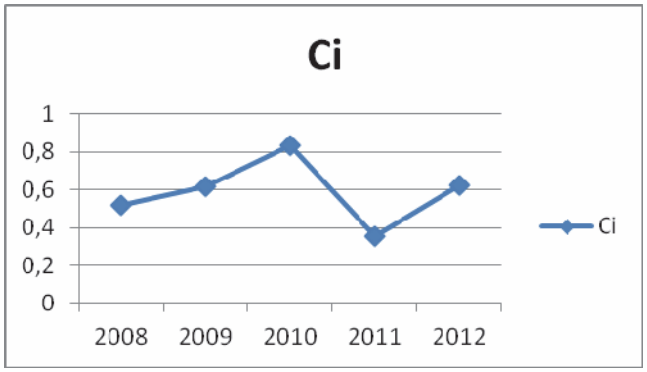
Table 6. Initial decision matrix of specific types of hazardous waste

	I_{17}	I_{18}	I_{19}	I_{20}	I_{21}	I_{22}	I_{23}	I_{24}	I_{25}
2008	0.0012	0.0152	0.0025	0.0012	0.0005	0.0081	0.0028	0.0002	0.0022
2009	0.0018	0.0061	0.0014	0.0005	0.0008	0.0024	0.0019	0.0004	0.0031
2010	0.0009	0.0025	0.0019	0.0004	0.0003	0.0033	0.0022	0.0003	0.0009
2011	0.0005	0.0126	0.0056	0.0014	0.0005	0.0188	0.0021	0.0005	0.0030
2012	0.0036	0.0048	0.0008	0.0005	0.0004	0.0076	0.0028	0.0001	0.0012

Table 7. Performance values due to years

	Years	C_i
C_1	2008	0.5154
C_2	2009	0.6148
C_3	2010	0.8350
C_4	2011	0.3523
C_5	2012	0.6234

As it is seen from the Table 7 the most effective year due to the sustainability perception of the company is 2010 just like the first study. When the subject is hazardous waste types, the worst performance value is obtained from the results gathered from the 2011's data. Graph 3 also shows the trend between years 2008 and 2012.



Graph 3. Performance values for specific types of hazardous waste from 2008 to 2012

5. CONCLUCISON

Sustainability is multidisciplinary concept which is used broadly and has been the trending topic for researchers from different fields. It can be considered as a process that provides society to use social, cultural, scientific, natural and human resources providently. In this context, textile industry has taken steps towards sustainability similarly to the other sectors and many researchers have conducted studies regarding to the subject.

In most cases, sustainability can be considered as the multi criteria decision making problem included environmental, social and economical aspects. There are lots of multi criteria decision making methods that procure an analysis tool and framework for decision makers which helps to determine a strategy by integrating tools from other disciplines. TOPSIS is one of these multi criteria decision making methods based on the distance of selective alternative to the ideal solution. Also this method enables us to evaluate conflicting indicators together.

In this study, data from sustainability reports of the corporate company included different fashion brands analyzed by using TOPSIS method. In order to assess the company's sustainable manufacturing performance, 25 indicators are identified as criteria and years between 2008 and 2012 are designated as decision points, in other word alternatives. The study focused on two cases. In the first case the initial matrix that contains all indicators is analyzed. In the second case, the indicators listed in the subtitle of "hazardous waste" have taken into account. Due to the results of the TOPSIS method, in both cases according to the performance values of each year, the company shows the best performance in the year of 2010 taking the score of 0,75 and 0,83 in the concept of sustainable manufacturing.

Both cases reveal that the best sustainability performance is recorded in 2010. If the annual reports are reviewed, it is seen that the Inditex Group set the strategic environmental plan and develop projects in the time period contains 2007-2010. Its main objective was to integrate the sustainability variable into the management of all Group activities. As a result of these efforts the year of 2010 could be the year when the most desirable performance is observed.

As a future work, indicators could be developed more detailed by considering the each category apart from the other categories. If the data is obtained related to the subject of economical and the social issues, new indicators could be added under new categories. Some other widely used multi-criteria decision making methods and other normalization processes in the same method could also be implemented then results compared with each other. In order to make company comparable with each other comparison of companies can be done by using this method in the aspect of sustainable manufacturing.

Finally, in our country, studies evaluating sustainability performance on sectoral basis is quite limited due to lack of data. Especially different sectors in our country should be analyzed with their counterparts in developed countries. This case is thought to be more helpful in specifying the strengths and weaknesses of Turkey's sustainability performance.

REFERENCES

1. United Nations, 1987, *Report of the World Commission on Environment and Development: Our common future/General Assembly Resolution 42/187*, Retrieved May 14, 2014 from http://www.un-documents.net/k-002988.htm
2. Allen, R, 1980, *How to Save the World*, New Jersey: Barnes and Noble.
3. Rao, V. R., 2007, "*Decision Making in The Manufacturing Environment*", London, Springer-Verlag, pp: 6.
4. Tekstil ve Konfeksiyon Sektöründe Ekoloji ve Ekolojik Etiketler İtkib Ar&Ge ve Mevzuat Şubesi, Mart, 2005, Retrieved March 10, 2014 from http://www.uenco.com.tr/docs/dokumanlar/eko_2.pdf
5. Ness, B., Urbel-Piirsalu, E., Anderberg, S. and Olsson, L., 2007, "Categorising Tools for Sustainability Assessment", *Ecological Economics*, *60*(3), pp: 498-508.
6. Erol, I., Sencer, S. and Sari, R., 2011, "A New Fuzzy Multi-Criteria Framework For Measuring Sustainability Performance of a Supply Chain", *Ecological Economics*, 70(6), pp: 1088-1100.
7. Öztel, A., Köse, M. S. and Aytekin, İ., 2012, "Kurumsal Sürdürülebilirlik Performansının Ölçümü İçin Çok Kriterli Bir Çerçeve: Henkel Örneği", *Tarih Kültür ve Sanat Araştırmaları Dergisi,* 1(4), pp: 32-44.
8. Singh, R. K., Murty, H. R., Gupta, S. K. and Dikshit, A. K., 2007, "Development of Composite Sustainability Performance Index for Steel Industry", *Ecological Indicators,* 7(3), pp: 565-588.
9. Diaz-Balteiro, L., Voces González, R. and Romero, C., 2011, "Making Sustainability Rankings Using Compromise Programming. An Application to European Paper Industry", *Silva Fennica*, 45(4), pp: 761-773.
10. Awasthi, A., Chauhan, S. S. and Omrani, H., 2011, "Application of Fuzzy TOPSIS in Evaluating Sustainable Transportation Systems", *Expert Systems with Applications*, 38(10), pp: 12270-12280.
11. Eş, A., 2008, *"Sustainability And Measuring Sustainability Performance Of Companies"*, Abant Izzet Baysal University, Institute of Social Sciences, Department Of Business Administration, Master Thesis, Bolu.
12. Reza, B., Sadiq, R. and Hewage, K., 2011, "Sustainability Assessment Of Flooring Systems in the City of Tehran: An AHP-Based Life Cycle Analysis", *Construction and Building Materials,* 25(4), pp: 2053-2066.
13. Pires, A., Chang, N. B. and Martinho, G., 2011, "An AHP-Based Fuzzy Interval TOPSIS Assessment for Sustainable Expansion of the Solid Waste Management System in Setúbal Peninsula, Portugal", *Resources, Conservation and Recycling,* 56(1), pp: 7-21.
14. Mulliner, E., Smallbone, K. and Maliene, V., 2013, "An Assessment of Sustainable Housing Affordability Using a Multiple Criteria Decision Making Method", *Omega,* 41(2), pp: 270-279.
15. Inditex Group Annual Report, Retrieved April 14, 2014 from http://www.inditex.com/documents/10279/18789/Annual_report_2012.pdf/1f394d3f-55cc-49b8-af13-14f87f8da3de
16. Hwang, C.L. and Yoon, K., 1981, *"Multiple Attribute Decision Making: Methods and Applications",* New York: Springer-Verlag.
17. Shih, H.S., Shyur, H.J. and Lee, E.S., 2007, "An Extension of TOPSIS for Group Decision Making", *Mathematical and Computer Modelling*, 45(7), pp: 801-813.