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A Vikor-Based Approach for Detergent Selection Problem From Sustainability Perspective

Research Article

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Abstract

The sustainability concept is getting more important due to the limited world carrying capacity and natural resources with increasing population around the world. As one of the Fast-Moving Consumer Goods, home cleaning has different impacts on both environment and health. In this context, using detergents reveal a research area because, they consist many ingredients that are worth to consider for sustainability and innovation. In daily life, detergents are consumed almost in every type of household activity; therefore, there is an increasing amount of detergent consumption. Even type of consumed detergent differs in terms of different regions, the most consumed type is defined as powder detergents according to European statistics. Such real-life cases complicate the decision-making process even more difficult because, they combine both qualitative and quantitative issues. In such cases, multi-criteria decision-making methods deal with uncertainties exist and contradicted criteria. Thus, the aim of the application is to detect the most appropriate detergent according to the sustainability dimensions by Vikor Method. First of all, five most purchased powder detergents were determined from top FMCG companies' annual reports and some related articles in literature. Secondly, algorithm of the Vikor Method was coded on MATLAB R2018a software and then, gathered data was integrated to evaluate the identified powder detergent options under sustainability metrics. As a result of this study, the most effective criteria are active ingredient and foam height from customer perspective without considering market share and retail price per net weight. Companies should focus on reducing negative effects of active ingredients while satisfying customer expectations and this ensures the preferability of a powder detergent from sustainability perspective.

Keywords: Detergents, Multi-criteria Decision Making, Sustainability, Vikor Method.

Özet

Dünya genelinde artan nüfus ile sürdürülebilirlik kavramı, Dünya'nın sınırlı taşıma kapasitesi ve doğal kaynak kapasitesine bağlı olarak git gide önem kazanmaktadır. Hızlı tüketim mallarından biri olan ev temizliği ürünlerinin hem çevre hem de sağlık üzerinde farklı etkileri vardır. Bu bağlamda, sürdürülebilirlik ve inovasyon için dikkate alınmaya değer birçok bileşen içeren deterjan kullanımı bir araştırma alanını ortaya çıkarmaktadır. Gündelik hayatta deterjanlar hemen hemen her türlü ev aktivitesinde tüketilmektedir. Bu nedenle, her geçen gün daha da artan miktarda deterjan tüketimi söz konusudur. Her ne kadar farklı bölgelere göre tüketilen deterjan türü farklılık gösterse de Avrupa istatistiklerine göre en çok tüketilen türün toz deterjanlar olduğu saptanmıştır. Hem nitel hem de nicel konuları birleştiren bu tür gerçek yaşam vakaları karar verme sürecini daha da zorlaştırmaktadır. Bu gibi durumlarda, belirsizlikler ve birbiriyle çelişen kriterler, çok kriterli karar verme yöntemleri ile değerlendirilmektedir. Tüm bu nedenlerle, bu uygulamanın amacı Vikor Metodu ile sürdürülebilirlik boyutlarına göre en uygun deterjan alternatifini tespit etmektir. İlk olarak, en çok satın alınan beş toz deterjan, en iyi FMCG şirketlerinin yıllık raporlarından ve literatürdeki bazı ilgili makalelerden belirlenmiştir. İkinci adımda, Vikor Metodu algoritması MATLAB R2018a yazılımına kodlanmış ve daha sonra, belirlenen toz deterjan seçeneklerini sürdürülebilirlik ölçütleri altında değerlendirmek için toplanan veriler MATLAB koduna entegre edilmiştir. Bu çalışma sonucunda, pazar payı ve net ağırlık başına perakende fiyatı dikkate alınmaksızın, müşteri açısından en etkili kriterlerin aktif bileşenler ve köpük yüksekliği olduğu saptanmıştır. Firmalar, müşteri beklentilerini karşılarken aktif bileşenlerin olumsuz etkilerini azaltmaya odaklanmalıdırlar. Bu sayede, sürdürülebilirlik açısından ürettikleri toz deterjanın tercih edilebilirliğini sağlamış olacaklardır.

Anahtar Kelimeler: Çok Kriterli Karar Verme, Deterjanlar, Sürdürülebilirlik, Vikor Metodu.

1. INTRODUCTION

Sustainability is a concept of integrating environment, economy and social areas in a way that can live together (Appleton, 2006, p. 3–18). By growing number of populations around the world, sustainability concept is getting more importance because of limited world carrying capacity and natural resources. In this case, governments have been started to make regulations about sustainable development and take actions in environmental, operational, financial and managerial processes within the country. There are some major areas which have to principally consider due to their negative effects especially on environment. As one of the Fast-Moving Consumer Goods sector area which is home cleaning has different impacts on both environment and health. In this context, using detergents reveal a research area because, they consist many ingredients that are worth to consider for sustainability and innovation (Hauthal, 2008, p. 30–42). The effects of each ingredient must be measured and consumers should prefer the least damaging product type. This decision problem needs a method which takes into account defined criteria and weight of each one. In the literature, the majority of multi-criteria decision-making problems tend to either discrete selection or customization of mathematical programming problems; however, an integrated multi-criteria decision analysis is sensitive to include both (Belton & Stewart, 2002). Multi-criteria decision-making involves identifying the optimal alternative between multiple, conflicting and interactive criteria (Yücenur, 2017, p. 779). This method, introduced by Opricovic & Tzeng (2007), focuses on sorting and selecting a number of alternatives and identifies conciliatory solutions that help the decision-maker reach the target for a problem with conflicting criteria. Multi-criteria decision-making methods are applied in many areas. Methods that use many qualitative and quantitative data are used in calculations which take into account different performance criteria and weights can be summarized such as TOPSIS, ELECTRE, AHP, ANP,

DEMATEL etc. (Eleren & Karagül, 2008, p. 1–14). In literature, Lee et al. (2009) was applied to the Vikor Method to prioritize land use restriction strategies in the Tseng-Wen reservoir basin. Sayadi et al. (2009) was used the extended Vikor Method to solve decision making problems with intermittent numbers. Chatterjee et al. (2009) proposed the Vikor and Electre methods for material selection. Opricovic & Tzeng (2007) compared four multi-criteria decision-making methods: Topsis, Promethee, Electre and Vikor and found the Vikor Method as the best evaluation method.

2. PROBLEM DEFINITION AND OBJECTIVES

In daily life, detergents are consumed almost in every type of household activity; therefore, there is an increasing amount of detergent consumption. Even type of consumed detergent differs in terms of different regions, the most consumed type is defined as powder detergents according to European statistics (European Ecolabel Commission, 2011, p. 1–39). Such real-life cases complicate the decision-making process even more difficult because, they combine both qualitative and quantitative issues. In such cases, multi-criteria decision-making methods are solved uncertainties exist and contradicted criteria with each other. Multi-criteria decision-making methods are used to support the decision-making process and generally to select one or more alternatives from a set of alternatives with different characteristics according to conflicting criteria or to rank these alternatives from the best to the worst according to their performance (Deng, Yeh & Willis, 2000, p. 963–973). In addition, unlike other decision-making methods, multi-criteria decision-making methods can be applied not only for quantitative but also for qualitative criteria. Furthermore, different results can be obtained even when one of these methods is applied to the same problem with the same assumptions and the same decision makers (Zanakis, Solomon, Wishart & Dublish, 1998, p. 507–529). However, complicated cases cannot be manually solved to avoid time consumption and calculation mistakes. Therefore, decision makers need to design the problem by using a tool which supplies a flexible solution process and quick response. In this study, MATLAB software was selected due to its features to give a useful answer decision makers needs (Mokhtarian, Sadi-Nezhad & Makui, 2014, p. 213–233). For all of the mentioned reasons, the aim of this study is to demonstrate how Vikor Method is applied on the evaluation of powder detergent alternatives based on sustainability criteria via using a software. In this sense, this study presents a realistic problem that can be encountered in daily life.

3. METHODOLOGY

The Vikor Method is a method of combining functions that represents the closest solution to the ideal solution (Opricovic & Tzeng, 2007, p. 514–529). For the majority, it determines a compromise solution that is close to ideal, providing maximum group benefit and minimum individual remorse. The alternatives are evaluated according to each criterion and the order of reconciliation is achieved by comparing the ideal solution proximity measure. There is a linear relationship between benefit and each criteria function, and the decision maker's preferences are expressed by weights. With this method, it is possible to normalize the criteria values having different solution values and eliminate the difference arising from the unit values of the criteria and to create a ranking index (Opricovic & Tzeng, 2007, p. 514–529).

In the Vikor Method, the reconciliation value is calculated using the L_p measure in Formula 1, which is used in compromise programming. This method performs linear optimization and calculates the ideal solution as a ratio.

$$Lpi = \left\{\sum_{j=1}^{n}\left[\frac{(f_j^* - f_{ij})}{(f_j^* - f_j^-)}\right]^p\right\}^{\frac{1}{p}} \quad (1)$$

$$1 \le p \le \infty;\ \ i = 1,2,\dots,m$$

At initial step of the Vikor Method, Formula 2 and 3 give the best f_i^* (max) and worst f_i^-(min) values for each criterion. However, it should be noted that; if a criterion would be minimized, the formulas are replaced and i shows comparison criteria and j shows the alternatives.

$$f_i^* = max_j f_{ij} \quad (2)$$

$$f_i^- = min_j f_{ij} \quad (3)$$

As the next step, the average group value (S_j) and the worst group value (R_j) were calculated by using Formula 4 and 5. w_i values indicate the assigned weight of each criteria.

$$S_j = \sum_{i=1}^{n} \frac{w_i(f_i^* - f_{ij})}{(f_i^* - f_i)} \quad (4)$$

$$R_j = max\left[\frac{w_i(f_i^* - f_{ij})}{(f_i^* - f_i)}\right] \quad (5)$$

Then, maximum group benefit value (Q_j) was calculated based on Formula 6. Here, v is the weight value for the strategy that will create the maximum group benefit, and $(1 - v)$ is the minimum regret of the opposing viewers. The v value determined by the group decision; *v > 0.5* represents the majority preference, *v = 0.5* consensus and *v < 0.5* veto for maximum group benefit in the Vikor Method.

$$Q_j = \frac{v(S_j - S^*)}{S^- - S^*} + \frac{(1-v)(R_j - R^*)}{R^- - R^*} \quad (6)$$

All of the calculated S_j, R_j and Q_j values are ordered from the smallest to the biggest; after, acceptable advantage C_1 and acceptable stability C_2 clusters are defined. Clusters C_1 and C_2 are determined in order to the order of S_j, R_j and Q_j values. For taking place in the any alternative to take place in the C_1 set, it must provide the following formula.

$$Q(A_2) - Q(A_1) \ge DQ \quad (7)$$

$$DQ = \left(\frac{1}{(1-m)}\right), m: number\ of\ alternatives$$

According to the order of Q_j, if the A_2 alternative takes place after the A_1 alternative and provides the formula, then the A_1 decision point is in the C_1 group. This calculation method is applied to all Q_j values and it is determined whether the alternatives are in C_1 set. The set of acceptable stability (C_2) consists of alternatives that are in the same order in the entire order of S_j, R_j and Q_j. Alternatives in both sets C_1 and C_2 show stable decision points according to sequencing logic.

4. APPLICATION

In this study, five most purchased powder detergents were determined from top FMCG companies' annual reports and some related articles in literature. MATLAB R2018a software was selected as measurement tool because, it is very flexible and useful for R&D activities. Furthermore, it was understood that there is an insufficient number of papers to generate an algorithm by using a tool about Vikor Method in literature. The aim of the application is to detect the most appropriate detergent brand according to the sustainability dimensions by Vikor Method. The application of the Vikor Method to evaluate the identified powder detergent options under sustainability metrics was coded on MATLAB software.

First of all, five different powder detergent alternatives and 12 different criteria (see Table-1) have been defined from 14 selected highly cited sustainability reports and articles. The values in the Table-1 are determined from the annual reports of global detergent manufacturers, researchs in the literature and articles given as reference. Then, the decision matrix which includes data set has been entered into the software.

Table 1. Table of Powder Detergent Alternatives and Sustainability Evaluation Criteria

Products	**1**	**2**	**3**	**4**	**5**
Market share	2.5	4.8	14.8	10.9	4.9
Retail price/net weight	0.205	0.22	0.1015	0.096	0.08
Packing quality	2	1.6	2	1.6	1.6
Detergency	21.53	25.38	17.78	21.03	18.64
Active ingredient	11.68	10.72	13.46	9.73	15.49
Sodium carbonate built-up	10	7.66	9.16	7.87	7.78
Active alkalinity	6.37	6.73	5.65	7.28	7.33
Total phosphates	4.1	6	5.93	5.99	5.99
Sodium triphosphate	3	6	6	6	6
Foam height	3.94	1.72	4	2.5	2.56
Moisture	3.35	3.35	2.99	3.71	3.66
Fragrance	2	2	1	1.5	2

The alternatives were named as Detergent 1, Detergent 2, Detergent 3, Detergent 4 and Detergent 5, and the criteria based on sustainability metrics were defined as market share, retail price per net weight, packing quality, detergency, active ingredient, sodium carbonate built-up, active alkalinity, total phosphates, sodium triphosphate, foam height, moisture and fragrance which were detected during literature review. Then, the benefit vector considering effects of each criteria on sustainability was defined which is given as Table-2 below:

Table 2. Benefit Vector

Criteria	1	2	3	4	5	6	7	8	9	10	11	12
Benefit	1	0	1	1	0	0	0	0	0	1	0	1

As the next step, the arithmetic means of the importance given by the decision makers for the criteria were entered into the weight vector w (see Table-3).

Table 3. Weight Vector

Products	**1**	**2**	**3**	**4**	**5**
Weights based on market share	2.5	4.8	14.8	10.9	4.9

In case of the aim of benefit maximization and damage minimization, max_j and min_j values were calculated by data gathered from columns of the decision matrix. After, both calculations of the average group value (S_j) and the worst group value (R_j) were integrated as another part of MATLAB code which was followed by the calculation of maximum group benefit value (Q_j) and ascending ordering of S_j, R_j, Q_j values. At the end of the coding process, MATLAB was run and the outputs were given as below:

- The order of preference of different powder detergent alternatives based on defined criteria: 2, 4, 1, 5, 3.
- The most preferable powder detergent alternative due to sustainability metrics: 2.

The results show that the most effective criteria on preference rank are active ingredient and foam height without considering market share and retail price per net weight criteria. It can be inferred that ordering of alternatives basically considers value creation of the product per environmental effect. Under this view, although higher rate of active ingredient decreases the probability of preference of the product due to sustainability evaluation; however, foam height is an advantageous criterion for consumers more tending to prefer that product. Thus, this measurement can be represented as a rate of foam height effectiveness per unit of active ingredient. On the other hand, the least preferable powder detergent was detected as Detergent 3 because of containing the second highest rate of active ingredients, the highest rate of sodium carbonate built-up and the smallest rate of fragrance even though it has more effective amount of chemicals inside.

5. CONCLUSION

United Nations Brundtland Commision refers sustainability as “meeting human needs without compromising the ability of future generations to meet their own needs.”(United Nations, 1987) In addition to environmental issues, this concept also involves social and economic resources. Today, there is an increasing awareness of sustainability both in governments and populations. Many consumers tend to compare the product alternatives at first, and then prefer more sustainable one to avoid bringing damaging on ecology. Not only consumers, but also many companies started to take preventive actions against to consume resources, energy more than adequate amount in their manufacturing operations and waste creation especially in chemical-based processes. Detergent selection problem is important for sustainability due to detergents’ chemical production and intensive usage. According to literature research, it was investigated that the most consumed household laundry detergent type is powder detergent because, they can be supplied with higher volume in a package to reduce selling price and they can be used any amount as much as a consumer want. Within this study, powder detergents were evaluated with Vikor Method which is an effective method when decision-maker is not experienced how to make a preference and tried to decide with analyzing both quantitative and qualitative data. As a result, the most preferable powder detergent type was detected as creating more value for consumer per negative effect by active ingredients under sustainability perspective. As future directions of the study, the same analysis will be managed by

more sustainability criteria and more alternatives combined powder, liquid and tablet detergents. Besides, decision-makers' brand preferences will be considered at the beginning of the analysis which make the data set more complex with unpredictable qualitative data.

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