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Selecting the most successfull recycling strategy over daily consumption products: application of q-Rung Orthopair Fuzzy Topsis method

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Abstract: Recycling is the process of collecting and reusing that helps the countries to achieve their sustainable development goals. This study, for the first time in the literature, considers the recycling of many daily consumption products as a decision-making problem with the q-rung orthopair fuzzy (q-ROF) approach. In Turkey, recycling initiatives are primarily led by the government and municipalities, involving either reprocessing in public facilities or collaboration with private enterprises. The research evaluates the effectiveness of recycling strategies, considering paper, plastic, textiles, batteries, frying oils, electronics, glass, and wood as alternative products. Criteria such as convertibility rate, resource usage for recycling, converted product lifespan, recycling process complexity, economic gain, product consumption rate, and trading opportunities are employed in the decision-making process. The q-rung orthopair fuzzy Technique for Order Preference by Similarity to Ideal Solution (q-ROFTOPSIS) method is applied to assess these criteria. Decision makers, comprising a recycling expert, a recycling business engineer, and an academician specializing in recycling studies, contribute to the evaluation. The study reveals electronic products as the most successful in recycling, while frying oils exhibit the least success.

En Başarılı Geri Dönüşüm Stratejisinin Gündelik Tüketim Ürünleri Üzerinden Seçilmesi: q-ROF Topsis Yöntemi Uygulaması

Anahtar Kelimeler
Geri dönüşüm,
q-ROF Topsis,
Gündelik tüketim ürünleri

Öz: Dönüşüm, ülkelerin sürdürülebilir kalkınma hedeflerine ulaşmalarına yardımcı olan toplama ve yeniden kullanma sürecidir. Bu çalışma literatürde ilk kez birçok günlük tüketim ürününün geri dönüşümünü q-rung orthopair fuzzy (q-ROF) yaklaşımıyla bir karar verme problemi olarak ele almaktadır. Türkiye'de geri dönüşüm girişimlerine genellikle hükümet ve belediyeler tarafından liderlik edilmekte olup, geri dönüşüm kamu veya özel işletmelerle iş birliği içerisinde yürütülmektedir. Araştırma kâğıt, plastik, tekstil, pil, kızartma yağları, elektronik, cam ve ahşap gibi alternatif ürünleri değerlendirerek geri dönüşüm stratejilerinin etkinliğini değerlendirmektedir. Dönüştürülebilirlik oranı, geri dönüşüm için kaynak kullanımı, dönüştürülmüş ürün ömrü, geri dönüşüm sürecinin karmaşıklığı, ekonomik kazanç, ürün tüketim hızı ve ticaret fırsatları gibi kriterler karar verme sürecinde kullanılmaktadır. Bu kriterleri değerlendirmek için q-rung orthopair fuzzy topsis (q-ROFTOPSIS) yöntemi uygulanmaktadır. Karar vericiler bir geri dönüşüm uzmanı, geri dönüşüm alanında çalışan bir mühendis ve geri dönüşüm çalışmalarında uzmanlaşmış bir akademisyenden oluşmaktadır. Çalışma, elektronik ürünlerin geri dönüşümde en başarılı ürün grubu olduğunu, kızartma yağlarının ise en az başarıyı gösteren ürün grubu olduğunu ortaya koymaktadır.

1. INTRODUCTION

Recycling plays a pivotal role in mitigating environmental impact, and among the diverse array of daily consumption products, paper, plastic, textiles, and batteries stand out as critical materials to be responsibly managed. The recycling of paper not only conserves trees but also significantly reduces energy consumption compared to producing paper from raw materials. Similarly, plastics, notorious for their environmental persistence, can be transformed into new products through recycling, reducing the burden on landfills and the oceans. Textiles, often overlooked, contribute to immense waste, but recycling them can lead to the creation of sustainable fashion and insulation materials. Additionally, proper disposal and recycling of batteries are essential to prevent hazardous materials from contaminating the soil and water. By emphasizing the recycling of these everyday items, we contribute to a circular economy that minimizes waste and conserves valuable resources.

1.1. Literature Review

The literature review for this study will be bifurcated into two distinct components: an exploration of existing research in the field of recycling and an investigation into studies that leverage q-rung orthopair fuzzy sets (q-ROFs). This division aims to provide a comprehensive understanding of both the broader context of recycling practices and the specific application of q-ROFs in decision-making processes related to recycling strategies.

1.2. Literature Review On Recycling

Several studies have addressed the intricacies of recycling programs and waste management, employing diverse methodologies and decision-making tools. Wibowo & Deng [1] focused on e-waste recycling programs, utilizing multi-criteria decision-making methods and incorporating intuitionistic fuzzy sets (IFS) to navigate uncertainties. Huang & Li [2] developed a discrete event-based simulation model to optimize household appliance recycling networks, considering system performance, economic factors, and environmental and energy indices. Chakraborty & Saha [3] tackled the multi-criteria decision-making problem of recycling lithium-ion batteries, determining the most effective system. Su et al. [4] utilized the TOPSIS method to analyze waste management in Taiwan, encompassing social, economic, and managerial aspects. Tortorella et al. [5], integrated lean production techniques with multi-criteria decision-making to optimize solid waste systems in Brazilian municipalities. Banar et al. [6] addressed the collection of electrical and electronic waste in Turkey, employing a decision-making approach with seven criteria and 16 alternatives. Zheng & Zhou [7] explored recycling processes for packaging products as a multi-criteria decision-making problem. Moro [8] delved into recycling concentrated mixtures, applying various criteria to a decision-making framework. Hadipour et al. [9] studied wastewater reuse in Iran within a decision-making context. Li et al. [10] evaluated express packaging recycling patterns using diverse multi-criteria decision-making methods. Koca & Behdioglu [11] examined recycling studies in the automotive industry, employing various criteria and decision-making methodologies. Stallkamp et al. [12] addressed the design of a recycling network for plastic waste in Europe using multi-criteria decision-making. Makarichi et al. [13] developed a multi-criteria decision-making approach to support solid waste management in Zimbabwe. Hanan et al. [14] evaluated paper recycling management systems in the Isle of Wight as a multi-criteria decision-making problem. Bhuyan et al. [15] explored recycling strategies for lithium-ion batteries in India, employing diverse multi-criteria decision-making methods in their study.

1.3. Literature Review On q-ROFs

In recent studies, various applications of q-rung orthopair fuzzy (q-ROF) methods in multi-criteria decision-making have been explored across different domains. Dinçer & Yüksel [16] assessed the risks associated with nuclear energy investments using the SWARA and ELECTRE methods, incorporating q-ROFs. Seikh & Mandal [17] focused on the location selection problem for software operating units, employing q-ROFs. Oraya et al. [18] utilized q-ROFs in a multi-criteria decision-making approach to evaluate the impact of delays in residence construction. Khan et al. [19] introduced a novel operator for stock selection in the market, applying q-ROFs to multi-criteria decision-making. Naz et al. [20] analyzed river crossing projects with q-ROFs, considering various criteria. Erdebilli et al. [21] addressed the sustainable selection of private health insurance in Turkey, employing q-ROFs. Aytekin et al. [22] identified critical lean 6 sigma methods using q-ROFs to optimize critical business processes. Pınar & Boran [23] utilized q-ROFs for supplier selection, introducing a new distance measurement model in their study. Alkan & Kahraman [24] discussed state strategies against Covid-19 using the q-ROFs TOPSIS method. Mishra & Rani [25] applied q-ROFs to select sustainable recycling pairs, while Yang & Chang [26] used q-ROFs for the optimal selection of garbage separation areas. Pınar et al. [27] employed q-ROFs in addressing the green supplier selection problem.

2. MATERIAL AND METHOD

2.1. Fuzzy Sets

Fuzyy sets (Fs): A fuzzy set A in the universe of discourse $X = \{x_1, x_2, \ldots, x_3\}$ is a set of ordered pairs: $A = \{\langle x, \mu_A(x)\rangle \mid x \in X\}$ where $\mu_A(x) \rightarrow [0,1]$ is the membership degree, Zadeh [28].

Intuitionistic Fuzzy Sets (IFs): An intuitionistic fuzzy set A in X can be described as: $A = \{\langle x, \mu_A(x), \nu_A(x)\rangle \mid x \in X\}$ where the functions $\mu_A(x) \rightarrow [0,1]$ and $\nu_A(x) \rightarrow [0,1]$ shows membership degree and non-membership degree of x, respectively, Atanassov [29].

Pythagorean Fuzzy Sets (PFs): Pythagorean fuzzy sets membership degree couple of values (a, b) such that $a, b \in [0,1]$ as follows: $a^2 + b^2 \leq 1$ where $a = A_Y(x)$, membership degree of x in A and $b = A_N(x)$ the non-membership degree of x in A, Yager [30].

q-Rung Orthopair Fuzzy Sets (q-ROFs): A fuzzy sets A of X given as $A = \{\langle x, \mu_A(x), \nu_A(x)\rangle \mid x \in X\}$ where $\mu_A(x) \rightarrow [0,1]$ shows membership degree and $\nu_A(x) \rightarrow [0,1]$ shows non-membership degree of $x \in X$ with condition given: $(\mu_A(x))^q + (\nu_A(x))^q \leq 1$, Yager [30].

Figure 1 represents the compression of different fuzzy sets

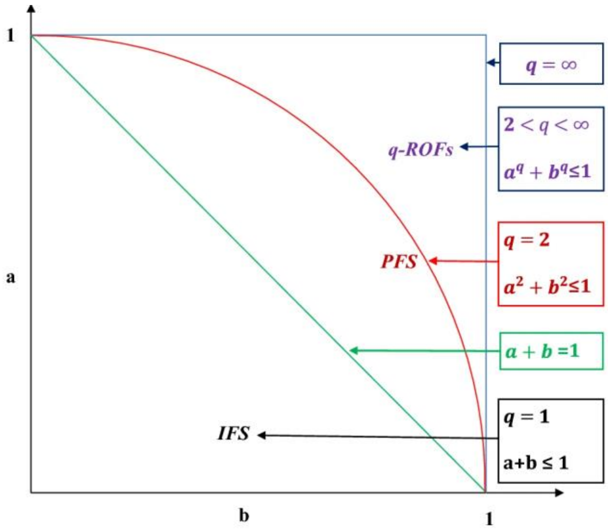

Figure 1. Comparing of fuzzy sets [23]

2.2. Topsis

TOPSIS is a multi-criteria decision-making (MCDM) method used to determine the best alternative from a set of available options. It was developed to evaluate and rank alternatives based on their proximity to the ideal solution and the remoteness from the negative solution. The method involves comparing the alternatives against both positive and negative ideal solutions to establish their relative closeness or distance.

The implementation steps for q-ROFs TOPSIS are outlined in detail below:

Step 1. Create a decision matrix with linguistic variables which's are taken from decision makers for alternatives and criteria. The set of alternatives, criteria and decision makers are shown below.

$A_i = \{A_1, A_2, \dots \dots, A_n\}$, $i = 1,2,\dots,n$ represent set of alternatives.

$C_j = \{C_1, C_2, \dots \dots, C_m\}$, $j = 1,2,\dots,m$ represent set of criteria.

$DM_k = \{DM_1, DM_2, \dots \dots, DM_t\}$, $k = 1,2,\dots,t$ represent set of decision makers weights where $DM_k > O$ and $\sum_{k=1}^{t} DM_k = 1$

Table 1 shows linguistic scale which also used by Alkan & Kahraman [24] given below. (μ: membership degree and ν: non-membership degree).

Table 1. Linguistic scale for alternatives and criteria.

Liguistic term	**Linguistic scale for alternatives and criteria**	
	μ	**ν**
Certainly High Value-(CHV)	0,99	0,11
Very High Value-(VHV)	0,88	0,22
High Value-(HV)	0,77	0,33
Above Average Value-(AAV)	0,66	0,44
Average Value-(AV)	0,55	0,55
Under Average Value-(UAV)	0,44	0,66
Low Value-(LV)	0,33	0,77
Very Low Value-(VLV)	0,22	0,88
Certainly Low Value-(CLV)	0,11	0,99

Step 2. Convert linguistic variables as μ and ν pairs to obtain a numerical decision matrix.

Step 3. Calculate aggregated decision matrix by using equation (1) given below.

$$q-ROFWG(\tilde{Q}_1, \tilde{Q}_2, \dots \dots, \tilde{Q}_n$$

$$= \left(\prod_{i=1}^{n} \mu_{\tilde{Q}_i}^{DM_i}, \left(1 - \prod_{i=1}^{n} \left(1 - \nu_{\tilde{Q}_i}^{q}\right)^{DM_i} \right)^{\frac{1}{q}} \right) \dots \dots \dots \dots \dots \dots \dots \dots \quad (1)$$

Where q-ROFWG: q-rung orthopair fuzzy weighted geometric operator

$\tilde{Q}_i = (\mu_{\tilde{Q}_i}, \nu_{\tilde{Q}_i}), i = 1,2, \dots \dots, n$ be set of q-ROFNs

$q = 1,2,3, \dots$ is a value that helps to provide a stronger uncertainty and flexibility to decision makers.

Step 4. Calculate aggregated decision matrix for criteria by using equation 1.

Step 5. Calculate weighted aggregated decision matrix by using equation 2.

$$\tilde{Q}_1 \otimes \tilde{Q}_2 = \left(\mu_{\tilde{Q}_1}\mu_{\tilde{Q}_2}, \left(\nu_{\tilde{Q}_1}^{q} + \nu_{\tilde{Q}_2}^{q} - \nu_{\tilde{Q}_1}^{q}\nu_{\tilde{Q}_2}^{q} \right)^{\frac{1}{q}} \right) \dots \dots \dots \dots \quad (2)$$

where $\tilde{Q}_1 = (\mu_{\tilde{Q}_1}, \nu_{\tilde{Q}_1}), \tilde{Q}_2 = (\mu_{\tilde{Q}_2}, \nu_{\tilde{Q}_2})$ a set of q-ROFN

Step 6. Normalize the weighted aggregated decision matrix by using equation 3.

Let $\tilde{N}$ be normalized q-ROF decision matrix

$$\tilde{N} = \tilde{n}_{ij} = (\mu_{ij}, \nu_{ij}) = \begin{cases} (\mu_{ij}, \nu_{ij}), & if\ crit.\ is\ benefit\ keep\ it\ as\ it\ is \\ (\nu_{ij}, \mu_{ij},), & if\ crit.\ is\ cost\ than\ turn\ it\ to\ benefit \end{cases} \quad (3)$$

Step 7. Determine q-ROF positive ideal solution (q-ROFPIS) and q-ROF negative solution (q-ROFNIS) using by equation 4. and 5.

$$\tilde{N}_j^* = max\{S(N_{1j}), S(N_{2j}), \ldots \ldots, S(N_{mj})\}, j = 1,2, \ldots \ldots, n \quad (4)$$

$$\tilde{N}_j^- = min\{S(N_{1j}), S(N_{2j}), \ldots \ldots, S(N_{mj})\}, j = 1,2, \ldots \ldots, n \quad (5)$$

where $S(\tilde{N})$ is the score function of q-ROFN and $S(\tilde{Q}) = \mu_{\tilde{Q}}^q - \nu_{\tilde{Q}}^q$

Step 8. Obtain the separation measures by calculating the distances for each alternative according to positive-ideal $(\tilde{N}^*)$ and negative-ideal solutions $(\tilde{N}^-)$. Then calculate distances between each alternatives by using Euclidean distance function 6. and 7. given below.

$$d(N_i, N^*) = \left(\frac{1}{2n}\sum_{j=1}^{n}\left(\left|\mu_{ij}^q - (\mu_j^*)^q\right|^2 + \left|\nu_{ij}^q - (\nu_j^*)^q\right|^2\right)\right)^{1/2} \quad (6)$$

$$d(N_i, N^-) = \left(\frac{1}{2n}\sum_{j=1}^{n}\left(\left|\mu_{ij}^q - (\mu_j^-)^q\right|^2 + \left|\nu_{ij}^q - (\nu_j^-)^q\right|^2\right)\right)^{1/2} \quad (7)$$

Step 9. Calculate the relative closeness coefficient (CC_i) of alternatives by using equation 8.

$$CC_i = \frac{d(N_i, N^-)}{d(N_i, N^-) + d(N_i, N^*)} \quad (8)$$

Step 10. Rank the alternatives according to final scores and select alternative which has best (CC_i) value.

3. RESULTS

The recycling landscape in Turkey shows an average waste recycling rate of 7%, with packaging materials leading at 20%. Specific product recycling rates are as follows: paper (43%), plastic (27%), glass (12%), textile products (8%), and metal products (4%). The study identifies various recycling products as alternatives, emphasizing their importance in sustainable practices.

Here is information about these products:
Paper (A1): Constituting a third of solid waste, recycling paper and cardboard is crucial for saving landfill space. One ton of paper occupies approximately 3.3 cubic meters of landfill space, making paper recycling an effective strategy for conserving space and reducing the need for additional landfills.
Plastic (A2): Recycling plastic waste extends the life of landfills and protects non-renewable raw material resources. The energy-saving impact is significant, with 14,000 kWh saved for every ton of recycled plastic.
Textiles (A3): Recycling textiles prevents pollution, reduces energy and water consumption, and minimizes landfill requirements. This is particularly important given that synthetic fibers don't decompose, and natural fibers can emit greenhouse gases.
Batteries (A4): Proper battery recycling is vital to prevent the release of toxic substances like cadmium into water and soil. Cadmium contamination poses severe health risks through the food chain and drinking water.
Frying Oil (A5): Recycling waste oils protects groundwater and soil, preventing pollution and maintaining soil fertility. It also reduces the risk of fires and prevents unpleasant odors associated with improper disposal.
Electronics (A6): Recycling electronic waste is essential to prevent environmental harm and promote the reuse of valuable materials. Electronic waste often contains harmful substances like cobalt, barium, and mercury.
Glass (A7): Producing products with recycled glass reduces CO2 emissions and greenhouse gases by 40%, and it decreases ocean and sea pollution by 20%. Glass stands out for its infinite recyclability without quality loss.
Wood (A8): Recycling wood waste in specialized facilities ensures the efficient use of resources in wooden goods production. The key factor is ensuring that recycled wood remains free from chemicals or substances that could compromise its structural integrity.

The study evaluates alternatives based on the following criteria:
Convertibility Rate (C1): This criterion gauges the percentage of recycled products obtained from the collected waste that can undergo recycling. 64
Resource Usage for Recycling (C2): This criterion assesses the amount of resources required to recycle the products.
Converted Product Lifespan (C3): It indicates the average duration it takes for the converted product to become waste again.
Recycling Process Complexity (C4): This criterion encompasses the difficulty level of the conversion processes, including collecting, storing, and reprocessing the product.
Economic Gain (C5): This criterion refers to the economic contribution of the product obtained through recycling.
Product Consumption Rate (C6): It evaluates how frequently the product in question is consumed.
Trading Opportunities (C7): This criterion expresses the economic significance of the recycled product within the sector.

In conclusion, this study unfolds in a comprehensive four-part structure, commencing with the definition of alternatives and criteria crucial to the decision problem. Subsequently, the literature review immerses into the vast realm of recycling and the nuanced application of q-rung orthopair fuzzy sets (q-ROFs). The second segment illuminates the q-ROF TOPSIS method, offering a clear understanding of its methodology. Moving forward, the third chapter including results the decision problem,
employing the established criteria to evaluate the identified alternatives. Finally, the fourth and last chapter

culminates in presenting the study's contributions, encapsulating key findings and underscoring the research's impact on the broader field.

In this section, the success status of the recycling strategies developed by the government, a focal point of this study, will be systematically assessed using the q-rung orthopair fuzzy TOPSIS (q-ROFTOPSIS) method. The evaluation will be conducted as a decision-making problem, considering the predefined alternatives and criteria. Each step of the q-ROFTOPSIS method will be followed to provide a comprehensive analysis of the recycling strategies. This approach aims to offer a nuanced understanding of the effectiveness and performance of state-developed recycling strategies, contributing valuable insights to the broader discourse on sustainable waste management.

Step 1. Obtained linguistic evaluations by using Table 1 from 3 different decision makers and results given in Table 2.

Table 2. Linguistic decision matrix for each decision maker.

	DM1								DM2								DM3							
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**
C1	CHV	VHV	HV	HV	AV	AAV	HV	VLV	CHV	CHV	AV	VHV	VLV	HV	AAV	CLV	VHV	CHV	AV	HV	CLV	VHV	AAV	VLV
C2	HV	VHV	AAV	CHV	VHV	AAV	HV	AV	HV	VHV	HV	UAV	VHV	HV	AAV	LV	AV	AAV	UAV	HV	VHV	AAV	HV	LV
C3	LV	VHV	HV	UAV	CLV	AAV	UAV	AAV	UAV	AAV	VHV	AAV	UAV	HV	AV	AAV	HV	VHV	AAV	AAV	VLV	AAV	UAV	HV
C4	HV	HV	AV	LV	VHV	HV	HV	VHV	AV	AAV	HV	UAV	VHV	AAV	UAV	AV	AAV	HV	UAV	LV	CHV	HV	VHV	AV
C5	LV	UAV	LV	HV	AV	CHV	AAV	CLV	AV	UAV	UAV	HV	UAV	CHV	AV	VLV	LV	LV	VLV	AAV	UAV	CHV	VHV	VLV
C6	CHV	VHV	AAV	VHV	UAV	CHV	AAV	VLV	VHV	CHV	HV	VHV	AV	CHV	HV	LV	AAV	AV	AV	VHV	VLV	CHV	AV	UAV
C7	AAV	UAV	HV	AV	CLV	CHV	UAV	UAV	LV	CLV	AAV	UAV	CLV	VHV	VLV	LV	VLV	CLV	LV	UAV	CLV	HV	LV	VLV

Step 2 and ***Step 3***.
In step 2, linguistic evaluations converted to numerical values according to Table 1. Then we calculated Table 3 by using equation 1. Q number accepted 4, and DMs weight taken into consideration as (0,33-0,33-0,34) respectively.

Table 3. Aggregated decision matrix.

	A1		A2		A3		A4		A5		A6		A7		A8	
	μ	ν	μ	ν	μ	ν	μ	ν	μ	ν	μ	ν	μ	ν	μ	ν
C1	[0,951 0,173]		[0,952 0,172]		[0,615 0,507]		[0,805 0,306]		[0,235 0,934]		[0,766 0,362]		[0,964 0,413]		[0,175 0,950]	
C2	[0,687 0,446]		[0,798 0,347]		[0,605 0,539]		[0,696 0,516]		[0,880 0,220]		[0,694 0,413]		[0,732 0,378]		[0,391 0,724]	
C3	[0,484 0,664]		[0,800 0,344]		[0,764 0,364]		[0,577 0,549]		[0,220 0,935]		[0,694 0,413]		[0,474 0,631]		[0,696 0,412]	
C4	[0,654 0,467]		[0,732 0,378]		[0,570 0,565]		[0,363 0,741]		[0,916 0,200]		[0,732 0,378]		[0,670 0,517]		[0,642 0,501]	
C5	[0,391 0,724]		[0,399 0,706]		[0,316 0,799]		[0,731 0,379]		[0,474 0,631]		[0,990 0,110]		[0,685 0,458]		[0,175 0,950]	
C6	[0,830 0,342]		[0,780 0,426]		[0,653 0,468]		[0,880 0,220]		[0,374 0,762]		[0,990 0,110]		[0,653 0,468]		[0,318 0,797]	
C7	[0,361 0,782]		[0,174 0,972]		[0,549 0,623]		[0,474 0,631]		[0,110 0,990]		[0,874 0,264]		[0,317 0,798]		[0,316 0,799]	

Step 4. Linguistic evaluations converted to numerical values and calculated aggregated criteria weights by using equation 1. Shown in Table 4. Criteria divided into two type, cost and benefit. Criteria 2 marked as cost type and others marked benefit type.

Table 4. Linguistic evaluations of criteria for each decision maker and aggregated criteria weights.

					Type	
Criteria	**DM1**	**DM2**	**DM3**	**Aggregated**	**Cost**	**Benefit**
C1	HV	VHV	VHV	[0,842 0,272]		✓
C2	CHV	CHV	VHV	[0,951 0,173]	✓	
C3	AV	AAV	HV	[0,655 0,466]		✓
C4	LV	HV	AAV	[0,552 0,620]		✓
C5	VHV	HV	HV	[0,805 0,306]		✓
C6	UAV	AV	HV	[0,573 0,562]		✓
C7	LV	UAV	AAV	[0,459 0,670]		✓

Step 5. Weighted aggregated decision matrix calculated by using equation 2. And Table 5 shows the results.

Table 5. Weighted aggregated decision matrix.

	A1	A2	A3	A4	A5	A6	A7	A8
	μ ν	μ ν	μ ν	μ ν	μ ν	μ ν	μ ν	μ ν
C1	[0,801 0,283]	[0,802 0,282]	[0,518 0,516]	[0,678 0,345]	[0,1998 0,935]	[0,645 0,388]	[0,585 0,431]	[0,147 0,950]
C2	[0,653 0,449]	[0,759 0,352]	[0,575 0,540]	[0,662 0,518]	[0,837 0,238]	[0,661 0,416]	[0,696 0,382]	[0,372 0,725]
C3	[0,317 0,694]	[0,524 0,496]	[0,500 0,503]	[0,378 0,605]	[0,144 0,939]	[0,455 0,523]	[0,310 0,667]	[0,455 0,523]
C4	[0,361 0,659]	[0,404 0,637]	[0,315 0,696]	[0,200 0,798]	[0,506 0,621]	[0,404 0,637]	[0,370 0,676]	[0,355 0,670]
C5	[0,314 0,728]	[0,321 0,711]	[0,254 0,802]	[0,588 0,413]	[0,381 0,638]	[0,797 0,307]	[0,551 0,478]	[0,141 0,950]
C6	[0,475 0,579]	[0,447 0,600]	[0,374 0,615]	[0,504 0,565]	[0,214 0,797]	[0,567 0,562]	[0,374 0,615]	[0,182 0,825]
C7	[0,166 0,841]	[0,080 0,978]	[0,252 0,754]	[0,218 0,757]	[0,051 0,992]	[0,402 0,673]	[0,146 0,851]	[0,145 0,852]

Step 6. Normalized decision matrix created by equation 3. and results shown in Table 6.

Table 6. Normalized decision matrix.

	A1	A2	A3	A4	A5	A6	A7	A8
	μ ν	μ ν	μ ν	μ ν	μ ν	μ ν	μ ν	μ ν
C1	[0,801 0,283]	[0,802 0,282]	[0,518 0,516]	[0,678 0,345]	[0,1998 0,935]	[0,645 0,388]	[0,585 0,431]	[0,147 0,950]
C2	[0,449 0,653]	[0,352 0,759]	[0,540 0,575]	[0,518 0,662]	[0,238 0,837]	[0,416 0,661]	[0,382 0,696]	[0,725 0,372]
C3	[0,317 0,694]	[0,524 0,496]	[0,500 0,503]	[0,378 0,605]	[0,144 0,939]	[0,455 0,523]	[0,310 0,667]	[0,455 0,523]
C4	[0,361 0,659]	[0,404 0,637]	[0,315 0,696]	[0,200 0,798]	[0,506 0,621]	[0,404 0,637]	[0,370 0,676]	[0,355 0,670]
C5	[0,314 0,728]	[0,321 0,711]	[0,254 0,802]	[0,588 0,413]	[0,381 0,638]	[0,797 0,307]	[0,551 0,478]	[0,141 0,950]
C6	[0,475 0,579]	[0,447 0,600]	[0,374 0,615]	[0,504 0,565]	[0,214 0,797]	[0,567 0,562]	[0,374 0,615]	[0,182 0,825]
C7	[0,166 0,841]	[0,080 0,978]	[0,252 0,754]	[0,218 0,757]	[0,051 0,992]	[0,402 0,673]	[0,146 0,851]	[0,145 0,852]

Step 7. In this section positive ideal solution (q-ROFPIS) and q-ROF negative solution (q-ROFNIS) determined by using equation 4. and 5. Table 7 shows the results.

Table 7. Positive and negative ideal solutions.

Criteria	Positive ideal solution	Negative ideal solution
C1	[0,802 0,282]	[0,147 0,950]
C2	[0,725 0,372]	[0,238 0,837]
C3	[0,524 0,496]	[0,144 0,939]
C4	[0,506 0,621]	[0,200 0,798]
C5	[0,797 0,307]	[0,141 0,950]
C6	[0,504 0,562]	[0,182 0,825]
C7	[0,402 0,673]	[0,051 0,992]

Step 8. Separation measures calculated by using equation 6. and 7. and results given in Table 8.

Table 8. Separation measures of alternatives.

	A1	A2	A3	A4	A5	A6	A7	A8
$d(N_i, N^*)$	0,1766	0,2519	0,1922	0,1434	0,4147	0,1045	0,1762	0,3668
$d(N_i, N^-)$	0,3677	0,3641	0,3716	0,4114	0,1884	0,4502	0,3733	0,2712

Step 9* and *Step 10. Closeness coefficient calculated by using equation 8. Table 9 shows closeness coefficient and ranking of alternatives.

Table 9. Closeness Coefficient and Ranking of Alternatives.

	A1	A2	A3	A4	A5	A6	A7	A8
CC_i	0,6755	0,591	0,6591	0,7416	0,3124	0,8117	0,6793	0,425
Rank	4	6	5	2	8	1	3	7
Alternatives	paper	plastic	textile	battery	frying oil	electronic	glass	wood

4. DISCUSSION AND CONCLUSION

This study delved into evaluating the success rates of strategies designed for recycling commonly consumed daily-life products, posing it as a decision-making problem. The analysis considered 8 alternatives and 7 success criteria, employing the q-rung orthopair fuzzy TOPSIS (q-ROFTOPSIS) approach. Findings indicated that electronic products ranked as the most favorable alternative, followed sequentially by batteries, glass, paper, textile, plastic, wood, and oils.

The determination of decision makers' weights can be approached at diverse levels and through varied methodologies. Alternative distance operators, such as Hamming or Hausdorff, could replace the Euclidean distance operator used in this study. The chosen q value of 4 facilitated decision-making amid uncertainty; however, different values may warrant exploration in subsequent studies to enhance the method's adaptability and robustness.

The flexibility of the methodology was evident in the acknowledgment that decision maker weights could be computed at different levels and using various methods. Furthermore, the study highlighted the potential for testing different q values in future research, emphasizing the adaptability of the approach under varying degrees of uncertainty. The decision-making process, guided by q-ROFTOPSIS, represents a valuable contribution to the field, providing a nuanced understanding of the success rates of recycling strategies for everyday consumables.

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