Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani
PEACE

Multi-criteria decision analysis applied to waste packaging

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Keywords: circular economy, packaging, waste management
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Introduction

According to Eurostat data, 84.3 million tonnes of packaging waste were produced in the EU in 2021, which is equivalent to 188.7 kg of waste per person—11 kg more than in 2020. The amount of packaging waste produced per resident increased by 22.5% between 2010 and 2021. The most common packaging waste materials were cardboard and paper (40.3%), then plastic (19.0%), glass (18.5%), wood (17.1%), and metal (4.9%). Thus, it is crucial to strengthen green governance of packaging in order to reduce the pressure on resources and the environment that results from express packaging waste. Indeed, the significant development of e-commerce and the conveniences of this option have enabled people to appreciate the advantages in terms of convenience. However, the environmental and social challenges should be carefully analyzed. These dimensions should be coordinated with that of economic development goals (Jiang et al., 2023). The literature has shown that recycling models have costs and limitations that need to be addressed and that impact the choices of key stakeholders toward their involvement in the recycling chain (Ling et al., 2023). A multi-criteria approach enables the evaluation of the most sustainable alternatives in different sectors to propose change based on pragmatic sustainability (D'Adamo et al., 2023). This work aims to evaluate potential alternatives to achieve the goal of sustainability in the field of waste packaging.

Materials and method

This work is based on a multicriteria decision analysis (MCDA) approach. In this regard, several alternatives are identified: A1) empty return; A2) natural fibers; A3) recycled materials; A4) sustainable transportation; A5) human conditions; A6) digitization; A7) customer relations; and A8) landfill. The choice is thus to evaluate seven distinct alternatives to landfill use, which should be an undesirable choice. In order to consider the impact of these alternatives nine criteria are identified based on the literature and a pre-check conducted with two academic experts in the field: C1) durability and reusability; C2) ecological design; C3) green premium; C4) brand reputation; C5) green production process; C6) end of life; C7) optimization and safety of delivery; C8) social impact and C9) traceability.
The experts were chosen by combining academic and industrial profiles. The former were selected by sending an e-mail describing the objective and how the questionnaire would be involved. The latter were chosen by considering companies active in the field and sending data collection emails. As for the Analytic Hierarchy Process (AHP), it allows for the evaluation of the consistency of the pairwise judgments made by the experts by enabling the identification of the weights of the criteria that are found to be valid for all the alternatives examined. A 10-point value approach is instead required to assign values to all alternatives for each criterion considered. It should be noted that this analysis has a greater characteristic of subjectivity since it does not allow for the assessment of consistency. This aspect is also a limitation of this method, but it turns out to be a necessary choice in the absence of objective data on which to make the final choices.

Results and conclusions

The final step is to aggregate the different weights and values, assigning each expert the same relevance. This product will determine a sustainability value for each alternative, and evidently the highest value will identify the most promising solution to the topic examined in this work. The results of this work are preliminary, and for example Table 1 provides an evaluation in terms of AHP, and Table 2 those related to 10-point value.
The judgments provided by experts do not always appear to be convergent, and the advantage of MCDA is able to aggregate even different points of view. Preliminary data show that much attention is paid to redefining the production cycle that aims to be green. This requires a great deal of effort from companies in the sector, with the risk that consumers will not recognize this. In fact, while the potential added value may be considered important it needs to be seen if it then actually translates during the moment of purchase. However, such choices highlight that a proper strategy is based on their mix. At the level of alternatives, sustainable options are significantly preferred over landfill use, and again future directions of analysis should include an estimation of interaction within a dynamic model.

Table 1. AHP – An example

	C1	C2	C3	C4	C5	C6	C7	C8	C9		
C1	1	2	0.5	2	0.5	2	2	2	2	ʎmax	9.54
C2	0.5	1	0.25	2	0.25	0.5	2	2	0.5	CI	0.07
C3	2	4	1	4	0.5	4	4	4	4	CR	0.05
C4	0.5	0.5	0.25	1	0.25	0.5	2	0.5	0.5		
C5	2	4	2	4	1	4	4	4	4		
C6	0.5	2	0.25	2	0.25	1	2	2	2		
C7	0.5	0.5	0.25	0.5	0.25	0.5	1	0.5	0.5		
C8	0.5	0.5	0.25	2	0.25	0.5	2	1	0.5		
C9	0.5	2	0.25	2	0.25	0.5	2	2	1		
Total	8	16.5	5	19.5	3.5	13.5	21	18	15		

	C1	C2	C3	C4	C5	C6	C7	C8	C9	Total	Average
C1	0.13	0.12	0.10	0.10	0.14	0.15	0.10	0.11	0.13	1.08	0.12
C2	0.06	0.06	0.05	0.10	0.07	0.04	0.10	0.11	0.03	0.62	0.07
C3	0.25	0.24	0.20	0.21	0.14	0.30	0.19	0.22	0.27	2.02	0.22
C4	0.06	0.03	0.05	0.05	0.07	0.04	0.10	0.03	0.03	0.46	0.05
C5	0.25	0.24	0.40	0.21	0.29	0.30	0.19	0.22	0.27	2.36	0.26
C6	0.06	0.12	0.05	0.10	0.07	0.07	0.10	0.11	0.13	0.82	0.09
C7	0.06	0.03	0.05	0.03	0.07	0.04	0.05	0.03	0.03	0.39	0.04
C8	0.06	0.03	0.05	0.10	0.07	0.04	0.10	0.06	0.03	0.54	0.06
C9	0.06	0.12	0.05	0.10	0.07	0.04	0.10	0.11	0.07	0.72	0.08
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	9.00	1.00

Table 2. 10-point value – An example

	A1	A2	A3	A4	A5	A6	A7	A8
C1	10	2	2	1	1	2	3	1
C2	7	10	7	2	8	5	6	10
C3	9	8	6	7	8	8	9	1
C4	9	9	8	7	7	6	10	1
C5	7	7	6	4	6	8	3	3
C6	9	9	7	7	3	5	5	5
C7	8	6	7	9	3	10	5	1
C8	5	6	5	5	10	7	5	1
C9	9	7	5	8	7	8	1	1

Acknowledgements

This study was carried out within the PEACE (Protecting the Environment: Advances in Circular Economy) and received funding from the "Fondo per il Programma Nazionale di Ricerca e Progetti di Rilevante Interesse Nazionale (PRIN)" Investimento M4.C2.1.1-D.D. 104.02-02-2022, 2022ZFBMA4 funded by the European Union - Next Generation EU. This manuscript reflects only the authors' views and opinions, and can be considered responsible for them.

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