SAKARYA UNIVERSITY JOURNAL OF COMPUTER AND INFORMATION SCIENCES
http://saucis.sakarya.edu.tr/
e-ISSN: 2636-8129
Publisher: Sakarya University
Vol. 8, No. 2, 286-300, 2025
DOI: 10.35377/saucis..1596931
SAUCIS
SAKARYA UNIVERSITY
RESEARCH ARTICLE

Facilitating Decision-Making Processes in Packaging and Graphic Media: A Review of MCDM Methods from 2008 to 2024

Şeyma Bozkurt Uzan[1*]
[1] Beykent University, Faculty of Engineering and Architecture, Istanbul, Türkiye
ror.org/03dcvf827

Corresponding author:
Şeyma Bozkurt Uzan, Beykent University, Faculty of Engineering and Architecture
seymauzan@beykent.edu.tr

Article History:
Received: 05.12.2024
Revised: 22.02.2025
Accepted: 11.04.2025
Published Online: 17.06.2025

ABSTRACT
This study reviews how Multi-Criteria Decision Making (MCDM) methods, like AHP, TOPSIS, and VIKOR, transform packaging and graphic media decision-making. These tools simplify complex choices by evaluating multiple criteria, aiding in tasks like material selection and design optimization. The findings highlight that MCDM improves decision-making efficiency, accuracy, and sustainability. It also emphasizes the potential of integrating these methods with AI and machine learning to unlock further innovation. The study calls for standardizing data practices and fostering global collaborations to drive progress. This research provides a practical guide to harnessing MCDM for smarter, sustainable industry practices.

Keywords: Multi-Criteria Decision Making (MCDM), Packing and Graphic Media, Sustainability, Analytic Hierarchy Process (AHP), Design Optimization.

1. Introduction

In today's fast-paced world, making decisions can often feel overwhelming, especially in industries like packaging and graphic media, where choices are numerous and complex. Multi-Criteria Decision Making (MCDM) techniques have emerged as essential tools that help navigate these challenges. These techniques enable decision-makers to evaluate multiple, often conflicting criteria, ensuring they make informed choices that balance efficiency, sustainability, and consumer appeal.

Packaging is not just about wrapping a product; it's a vital part of delivering and marketing it. Similarly, graphic media is crucial in visually presenting and branding products. With consumers becoming increasingly conscious of sustainability and quality, the stakes are higher than ever. MCDM helps professionals in these fields systematically analyze their options, weighing factors like cost, environmental impact, and consumer preferences. For example, consider the challenge of designing a new eco-friendly package. Decision-makers must evaluate various materials and designs while considering production costs and consumer reactions. MCDM provides a structured approach to this complexity, allowing for more balanced decisions that align with business goals and consumer expectations.

A review of the current literature reveals a diverse range of studies employing MCDM techniques such as the Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR). These methodologies have been applied to tackle challenges ranging from supplier selection and material choices to optimizing sustainable product-package design and selecting flexible packaging equipment. However, a gap remains in comprehensive reviews that synthesize these studies and highlight their practical implications across the packaging and graphic media sectors. By detailing the data collection and analysis processes used in these studies, this research highlights how MCDM can significantly enhance decision-making efficiency and accuracy. The systematic approach often includes techniques for gathering data, such as surveys, expert interviews, and case studies, ensuring that the information is comprehensive and relevant. This thoroughness allows decision-makers to evaluate alternatives based on a well-rounded understanding of weighted criteria, ultimately leading to a 'best-fit' option. Moreover, the analysis processes typically involve advanced methodologies like AHP, TOPSIS, and VIKOR, which facilitate the ranking and prioritization of options based on multiple criteria. These methods streamline the decision-making process and improve transparency and objectivity, enabling stakeholders to understand the rationale behind each choice.

The comprehensive overview provided by this literature review underscores the critical role of MCDM in addressing complex decision-making problems in these fields. By synthesizing findings from various studies, it becomes evident that MCDM techniques are instrumental in navigating the multifaceted challenges faced by professionals in packaging and graphic media.

Cite as: Ş. Bozkurt Uzan. (2025). Facilitating decision-making processes in packaging and graphic media: A review of MCDM methods from 2008 to 2024. Sakarya University Journal of Computer and Information Sciences. vol. 8, no. 2, pp. 286-300, 2025 doi: 10.35377/saucis...1596931

As industries evolve and consumer expectations shift, leveraging MCDM can lead to more informed decisions aligning with business objectives and societal needs.

This research aims to bridge that gap by providing an in-depth literature review on the application of MCDM techniques in the packaging and graphic media sectors. By focusing on studies published between 2008 and 2024 from reputable academic sources like Elsevier, Scopus, Springer, and Emerald, this review will identify key articles that have made meaningful contributions to the field. We will explore the methodologies used, the challenges addressed, and the insights gained. The review will cover traditional MCDM approaches and look into innovative hybrid techniques that integrate multiple criteria while effectively handling uncertainty. Recent advancements have introduced fuzzy-based methods that account for imprecision in decision-making—an essential feature in today's dynamic environments where consumer preferences can shift rapidly.

Multi-criteria decision-making (MCDM) has been extensively used in engineering, logistics, and supply chain management. However, its application in the packaging and graphic media industries is still relatively limited. Existing research primarily focuses on material selection and general decision-making processes, leaving a gap in the structured comparison of different MCDM techniques within this sector. Furthermore, there is insufficient exploration of how artificial intelligence and automation can improve decision-making efficiency, particularly in sustainable packaging solutions. This study addresses these gaps by providing a systematic review of MCDM applications in packaging and graphic media, comparing various methodologies, and identifying future research opportunities to enhance decision-making processes in these industries.

In summary, this study seeks to consolidate existing research on MCDM applications in packaging and graphic media while offering valuable insights for future exploration. The findings suggest that MCDM techniques hold significant potential to enhance decision-making processes, leading to more sustainable and efficient outcomes. This research aims to inspire further advancements in the field by showcasing the methodologies and implications of previous studies. As the packaging and graphic media industries evolve with changing consumer demands and environmental considerations, robust decision-making frameworks like MCDM will be pivotal in shaping their future strategies. Through this exploration, we hope to empower industry professionals with the knowledge they need to make informed decisions that benefit their businesses and contribute positively to society and the environment.

2. Theoretical Framework

2.1 Multi-Criteria Decision Making (MCDM)

Multi-Criteria Decision Making (MCDM) is a sub-discipline of operations research that deals with decision-making problems involving multiple criteria. These problems are prevalent in various fields, including engineering, business, environmental management, and public policy. The primary importance of MCDM lies in its ability to provide a structured decision-making approach, helping decision-makers systematically evaluate multiple conflicting criteria. MCDM methods allow decision-makers to balance trade-offs, prioritize objectives, and arrive at more informed and rational decisions [1].

In recent years, the role of MCDM has expanded with advancements in computational techniques and data analytics. Traditional methods like AHP and TOPSIS have been widely used, but newer hybrid models integrating artificial intelligence (AI) and machine learning (ML) are enhancing decision-making capabilities [2]. These AI-driven approaches help process large datasets, automate weight assignments, and improve decision accuracy in complex scenarios [3].

Moreover, the growing emphasis on sustainability and efficiency has further increased the adoption of MCDM in supply chain management, smart manufacturing, and environmental planning. Decision-makers leverage these methods to evaluate trade-offs between cost, environmental impact, and performance metrics, ensuring optimal resource allocation [4]. As MCDM continues to evolve, integrating advanced technologies and interdisciplinary approaches will be key to addressing modern decision-making challenges effectively.

2.2 Commonly Used MCDM Methods

Several methods are widely used in MCDM to address decision-making problems. Some of the most prominent methods include the Analytic Hierarchy Process (AHP), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR). Each method has its unique approach and application areas. For instance, AHP is well-suited for hierarchical decision problems, while TOPSIS ranks alternatives based on their closeness to an ideal solution. VIKOR, on the other hand, is effective in situations requiring compromise solutions among conflicting criteria [5].

In addition to AHP, TOPSIS, and VIKOR, other notable MCDM methods include the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) and the Elimination and Choice Translating Reality (ELECTRE) method. PROMETHEE is particularly useful for outranking alternatives based on pairwise comparisons and effectively handles complex decision problems with multiple criteria [6]. ELECTRE, on the other hand, is widely used for its ability to deal with incomparability among alternatives, making it suitable for decision-making scenarios where clear dominance relationships are difficult to establish [7]. Furthermore, the Weighted Aggregated Sum Product Assessment (WASPAS) method has gained popularity for its simplicity and effectiveness in combining weighted sum and product models to evaluate

alternatives [8]. These methods, along with AHP, TOPSIS, and VIKOR, provide a comprehensive toolkit for decision-makers to address a wide range of MCDM problems, each offering unique strengths depending on the specific requirements of the decision context.

2.3 Application Areas

Multi-criteria decision-making (MCDM) techniques are widely used across various fields to tackle complex decision-making challenges. MCDM methods are crucial in resource allocation, waste management, and sustainability assessments in the environmental sector. For example, they help evaluate trade-offs between economic growth and environmental protection, ensuring decisions align with sustainable development goals [9]. In the business world, MCDM is invaluable for selecting suppliers, prioritizing projects, and shaping long-term strategies. It provides a structured way to weigh multiple factors, making it a go-to tool for supply chain management and corporate decision-making [10]. In engineering, MCDM methods are applied to material selection, design optimization, and infrastructure planning, where they help balance technical, economic, and environmental considerations to achieve the best outcomes [11]. The adaptability of MCDM techniques makes them indispensable in any field where decisions involve evaluating multiple, often conflicting, criteria.

2.4 Challenges and Future Directions

Despite their widespread use, MCDM techniques face several challenges. These include data collection and analysis complexity, the need for accurate and reliable data, and difficulty integrating MCDM with other decision-making tools and technologies such as artificial intelligence and machine learning [12]. Future MCDM research should address these challenges by developing more efficient and user-friendly methods, enhancing data integration capabilities, and exploring new application areas. Standardizing MCDM processes and promoting international collaborations can also help advance the field and improve decision-making practices globally [13].

2.5 The Packaging and Graphic Media

2.5.1 Role in product marketing and consumer perception

Graphic media shapes how consumers perceive products and enhance marketing strategies. By combining visual elements like images, typography, colors, and layout design, graphic media communicates a brand’s identity and captures the attention of potential customers. For instance, well-designed packaging or a visually appealing advertisement can instantly convey a brand’s values and create a lasting impression. In today’s competitive markets, businesses rely on graphic media to stand out and build emotional connections with their audience. Whether it’s through eye-catching social media posts, sleek product packaging, or immersive digital ads, graphic media helps brands convey trust, quality, and innovation, ultimately influencing purchasing decisions [14].

Studies have shown that consumers often make split-second judgments based on visual appeal, making graphic design a powerful tool for creating brand recognition and loyalty. For example, consistent use of colors and typography across marketing materials can reinforce brand identity and make it more memorable [15]. Additionally, the rise of digital platforms has expanded the role of graphic media, allowing brands to engage with consumers in more interactive and personalized ways. From Instagram ads to website design, businesses leverage graphic media to tell their stories and connect with their target audience on a deeper level [16].

In essence, graphic media is more than just aesthetics—it’s a strategic tool that bridges the gap between brands and consumers, turning visual appeal into tangible business outcomes.

2.5.2 Sustainability and environmental impact

Sustainability has become a vital consideration in the packaging and graphic media sectors. With increasing awareness of environmental issues, companies focus on developing sustainable packaging solutions that minimize ecological footprints. This includes using recyclable, biodegradable, or reusable materials and reducing packaging waste. The shift towards sustainable packaging helps environmental conservation, enhances the brand's reputation, and aligns with consumer preferences for eco-friendly products [17].

2.5.3 Technological advancements and innovations

Technological advancements are continuously transforming the packaging and graphic media industries. Innovations such as smart packaging, which include features like QR codes, NFC tags, and augmented reality, provide interactive and engaging experiences for consumers. These technologies offer improved product tracking, enhanced safety, and better consumer engagement. Additionally, advancements in printing technologies, such as digital printing and 3D printing, have revolutionized the design and production of packaging, allowing for greater customization and efficiency [18].

2.5.4 Challenges and Future Trends

The packaging and graphic media sectors face various challenges that require careful navigation. One of the most pressing issues is balancing cost and quality as businesses strive to create visually appealing and functional designs without exceeding budgets. At the same time, meeting stringent regulatory requirements and managing supply chain complexities add layers of

difficulty to the process [19]. Beyond these operational hurdles, staying ahead of rapidly changing consumer preferences and technological advancements demands constant innovation and adaptability [20]. For example, e-commerce has shifted consumer expectations, requiring packaging to be durable for shipping and visually striking for unboxing experiences.

Looking to the future, several trends are shaping the industry. Personalization is becoming a key focus as brands seek to create unique, tailored customer experiences. Advanced materials, such as biodegradable and lightweight options, are gaining traction as companies aim to reduce their environmental footprint. The adoption of circular economic principles is also on the rise, encouraging the reuse and recycling of packaging materials [21]. Additionally, the growing demand for sustainable packaging solutions and the emergence of smart packaging technologies—such as QR codes and NFC tags—drive innovation in the sector [22]. Companies that can effectively address these challenges and capitalize on emerging trends will be well-positioned to thrive in an increasingly competitive and dynamic market.

3. Research Methodology

Multi-Criteria Decision Making (MCDM) studies are widely used to optimize decision-making processes across various sectors. This research examines the use of MCDM in the packaging and graphic media sectors. The aim is to review the literature in this field and summarize the scope and findings of existing studies. The studies were selected from academic databases such as Elsevier, Scopus, Springer, and Emerald. Articles published between 2008 and 2024 were searched using the keywords "packaging," "MCDM," and "AHP" in their abstracts. Relevant articles were selected and presented in summary tables. This method comprehensively analyzes MCDM applications in packaging and graphic media. The research includes findings and methods that can contribute to sectoral applications. The results also offer significant recommendations for future studies. This way, decision-making processes in the packaging and graphic media sectors can be more efficient.

4. Findings

The literature review identified various studies on applying multi-criteria decision-making (MCDM) in the packaging and graphic media sectors. These studies, accessible through various academic databases, have been compiled and listed in Table 1. The table illustrates the scope and diversity of research conducted in this area. Each entry includes the title, authors, publication venue, and year of publication. The studies employ various MCDM techniques such as AHP, TOPSIS, and VIKOR. They address different problems within the sectors, from material selection to design optimization. The methodologies used in these studies are detailed, providing insights into data collection and analysis processes. Findings from these studies demonstrate the effectiveness of MCDM in improving decision-making processes. The results also highlight the potential for MCDM to enhance these methodologies. Overall, Table 1 provides a comprehensive overview of the significant research contributions in this field.

Table 1. Chronological Overview of Articles about MCDM in the Packaging and Graphic Media Sectors

No	Title	Methods Used	Data Source	Source	Year	Country
1	Multi-criteria evaluation techniques for sustainable packaging systems	AHP, LCA	Case Study, Surveys, Industry Reports	Journal of the Japan Packaging Institute	2008	Japan
2	A fuzzy ANP model for supplier selection as applied to IC packaging	FANP	Literature Review, Expert Opinions	Journal of Intelligent Manufacturing	2012	Netherlands
3	An Integrated MCDM Framework for the Selection of Sustainable Packaging Materials	AHP, TOPSIS, DEMATEL	Literature Review, Case Study	Environment, Development and Sustainability	2014	Switzerland
4	Comparative Analysis of MCDM Methods for Packaging Material Selection	FAHP-TOPSIS, FAHP-VIKOR, FAHP-ELECTRE, FAHP-PROMTHEE, VIKOR	Literature Review, Expert Opinions	Expert Systems with Applications	2014	UK
5	Sustainable product-package design in a food supply chain: A multi-criteria life cycle approach	BWM	Literature Review, Expert Opinions	Packaging Technology and Science	2018	UK

6	A multi-criteria assessment of alternative sustainable solid waste management of flexible packaging	ANP	Interviews, Questionnaires	Management of Environmental Quality	2019	UK
7	Why Biopolymer Packaging Materials are Better	TOPSIS	Interviews, Questionnaires	Environmental and Climate Technologies	2019	Germany
8	A novel multi-objective optimization approach for sustainable supply chain: A case study in the packaging industry	AHP	Literature Review, Case Study	Sustainable Production and Consumption	2019	Netherlands
9	Application of Shannon's entropy-analytic hierarchy process (AHP) for the selection of the most suitable starch as a matrix in green biocomposites for takeout food packaging design	AHP, Shannon entropy	Literature Review	Bioresources	2020	USA
10	An Integrated Fuzzy Multi-Criteria Decision-Making Method for Sustainable Packaging Materials Selection: An Application in Turkey	F-PROMETHEE DELPHI	Interviews, Questionnaires	Fresenius Environmental Bulletin	2020	Germany
11	Green packaging for durable engineering products in Iraqi markets	AHP	Interviews, Questionnaires	IOP Conference Series: Earth and Environmental Science	2021	UK
12	A Hybrid Multi-Criteria Decision-Making Method Proposal For The Solution Of The Packaging Supplier Selection Problem	F-AHP, F-WASPAS	Interviews, Questionnaires	Journal of Human and Social Sciences Research	2021	Turkiye
13	A Multi-Criteria Decision-Making Approach Using AHP for Pudak Packaging Supplier Selection	AHP	Supplier Data Collection	Journal of Agroindustrial Technology	2022	Indonesia
14	New hybrid AHP-QFD-PROMETHEE decision-making support method in the hesitant fuzzy environment: an application in packaging design selection	AHP, QFD, TOPSIS	Interviews, Questionnaires	Journal of Intelligent & Fuzzy Systems	2022	Netherlands
15	Industrial Packaging Performance Indicator Using a Group	AHP	Interviews, Questionnaires	Logistics	2022	Switzerland

	Multicriteria Approach: An Automaker Reverse Operations Case					
16	An innovative probabilistic hesitant fuzzy set MCDM perspective for selecting flexible packaging bags after the prohibition on single-use plastics	PHFS, WASPAS, AHP	Case Study	Scientific Reports	2023	UK
17	Proposal of a hybrid decision-making framework for the prioritization of express packaging recycling patterns	Fuzzy Group FUCOM, Fuzzy GRC-DANP, Fuzzy EDAS	Literature Review, Expert Opinions	Environment, Development and Sustainability	2023	Netherlands
18	An Integrated Multi-Criteria Decision-Making Framework for the Selection of Sustainable Biodegradable Polymer Food Packaging Applications	WSM, WPM, WASPAS, TOPSIS	Literature Review, Case Study	Environment, Development and Sustainability	2024	Netherlands
19	Life Cycle Assessment (LCA) and Multi Criteria Decision Analysis (MCDA) of eco-friendly packaging for dairy products and fourth range.	LCA, MCDA	Interviews, Expert Opinions	Procedia CIRP	2024	Netherlands
20	The Contribution of Sustainable Packaging to the Circular Food Supply Chain	BWM, SAW, AHP	Literature Review, Case Study	Packaging Technology and Science	2024	UK

*The articles mentioned in Table 1, 'Articles about MCDM in The Packaging and Graphic Media Sectors,' are cited in the References section for further details.

The following sections provide an introduction and detailed analysis of the three key points related to the table, including an overview and significance of the studies, methodologies and techniques used, and the findings and implications for the packaging and graphic media sectors.

4.1 Overview and Significance

The table provides a comprehensive overview of studies on implementing Multi-Criteria Decision Making (MCDM) in the packaging and graphic media sectors. It includes various essential details such as the titles, authors, publication venues, and years of publication. This structured presentation helps us understand the breadth and scope of research conducted in this area. Listing the studies in a tabulated format makes it easier for researchers to identify key trends and methodologies. Including publication years allows for analyzing how research in this field has evolved. The table highlights the diversity of problems addressed by these studies, ranging from material selection to design optimization. It also shows the different MCDM techniques, such as AHP, TOPSIS, and VIKOR. Each entry in the table provides a snapshot of the study's focus and findings. This makes it a valuable resource for anyone seeking insights into MCDM applications in packaging and graphic media. Overall, the table is useful for quickly accessing relevant research and understanding the field's current state.

4.2 Methodologies and Techniques

The table showcases a variety of methodologies and techniques used in the studies listed. The frequent use of MCDM techniques such as AHP (Analytic Hierarchy Process) indicates its popularity and effectiveness in packaging and graphic media. Studies employing TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) are also prominently featured, suggesting its relevance in this domain. The presence of VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) further emphasizes the diversity of MCDM methods being applied. Each study listed provides valuable insights into

how these techniques can be utilized to address specific industry challenges. The methodologies used in these studies are detailed, highlighting the data collection and analysis process. This detailed approach allows a better understanding of how MCDM techniques can be effectively applied. The variety of techniques also indicates no one-size-fits-all solution and different methods may be more suitable depending on the problem. By exploring these different methodologies, researchers can gain a deeper understanding of the strengths and weaknesses of each technique. This knowledge can be applied to future studies to improve packaging and graphic media decision-making processes.

4.3 Findings and Implications

The findings from the studies listed in the table have significant implications for the packaging and graphic media sectors. MCDM techniques have improved decision-making processes, leading to more efficient and effective outcomes. For example, studies on material selection have demonstrated how MCDM can help choose the most suitable materials based on multiple criteria. This can result in cost savings, improved product quality, and enhanced sustainability. Similarly, studies on design optimization have highlighted the benefits of using MCDM to create designs that meet various performance criteria. The findings also underscore the importance of data-driven decision-making in these sectors. The studies listed in the table provide a wealth of information that can be used to inform best practices and guide future research. They also offer practical recommendations that industry professionals can apply to improve their operations. The table highlights the significant contributions that MCDM research has made to the packaging and graphic media sectors and the potential for further advancements in this field.

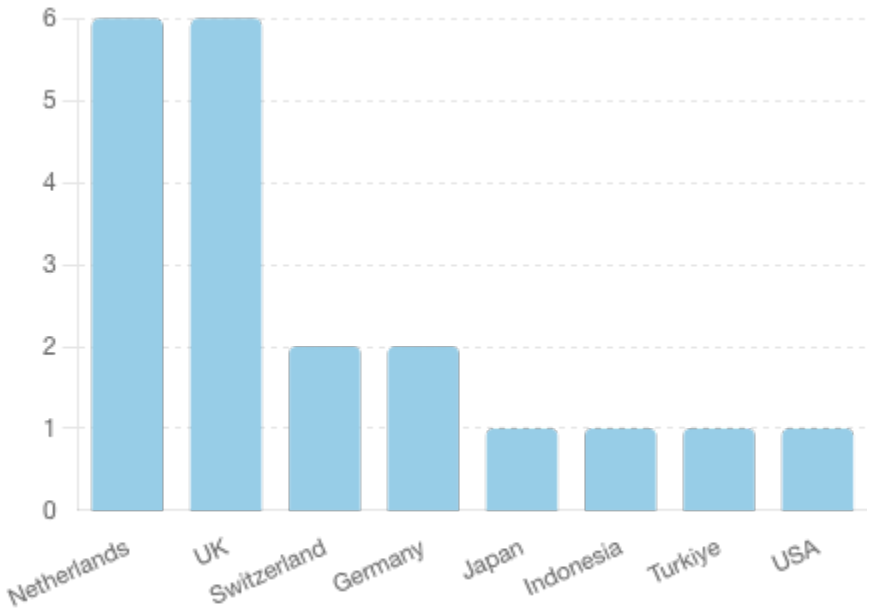

Figure 1. Sustainable Packaging Materials By Country

The chart highlights the distribution of studies on sustainable packaging materials across various countries. The Netherlands and the UK led the research, with six studies indicating a strong focus on sustainable packaging in these regions. This could be attributed to advanced environmental policies and a higher emphasis on sustainability practices in these countries. Switzerland and Germany each contribute two studies, reflecting their commitment to innovative packaging solutions. Japan, Indonesia, Turkey, and the USA each have one study, suggesting emerging interest and ongoing efforts in sustainable packaging research. The presence of multiple studies from different countries demonstrates a global recognition of the importance of sustainable packaging. It also highlights the collaborative nature of research in addressing environmental challenges. The variation in the number of studies might be influenced by factors such as funding availability, research infrastructure, and governmental support. Overall, the chart underscores the significant role of international contributions in advancing sustainable packaging technologies and practices.

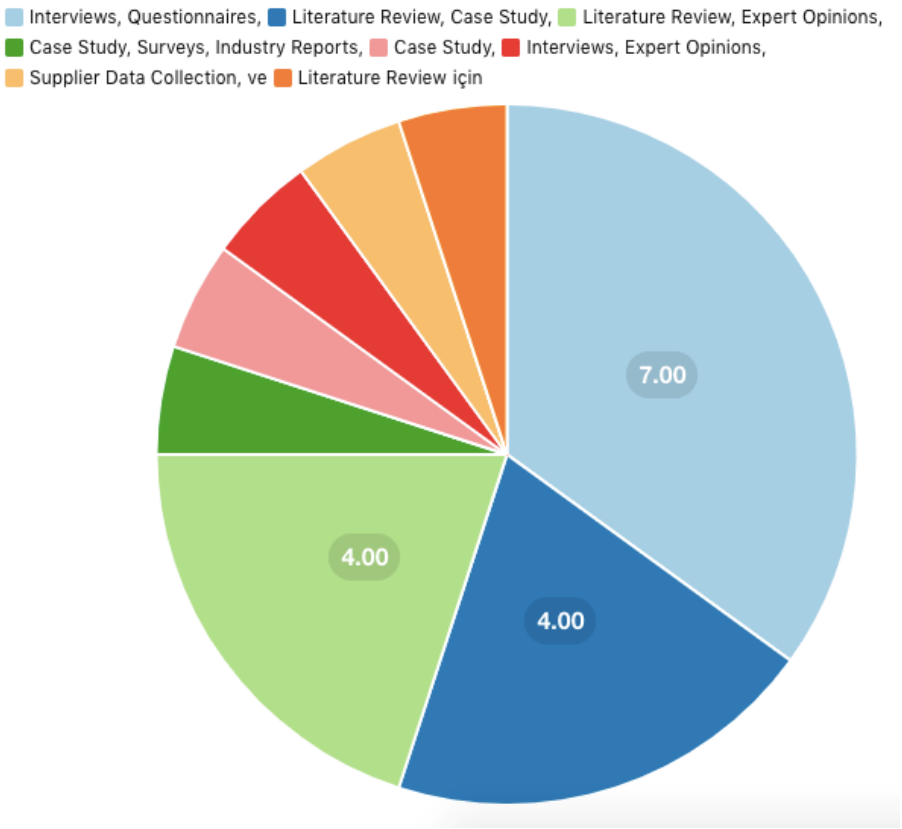

Figure 2. The Distribution of Data Sources Used in Sustainable Packaging Materials Studies

The pie chart illustrates the distribution of various data sources utilized in studies on sustainable packaging materials. A significant portion of the studies, 35%, rely on interviews and questionnaires, indicating a strong preference for collecting primary data directly from industry experts and stakeholders. This method provides in-depth insights and practical perspectives, crucial for understanding real-world applications and challenges.

Literature reviews combined with case studies constitute 20% of the data sources. This combination allows researchers to contextualize their findings within existing knowledge and apply theoretical frameworks to practical scenarios. Another 20% of the studies utilize literature reviews and expert opinions, highlighting the importance of synthesizing existing research and leveraging expert knowledge to inform decision-making processes.

Smaller segments of the chart represent other data sources, each making up 5% of the total. These include case studies, literature reviews alone, supplier data collection, and combinations of interviews with expert opinions or case studies with industry reports. The diversity in data sources reflects the multifaceted nature of research in sustainable packaging, where different methodologies are employed to address various aspects of the field.

The distribution suggests that while primary data collection through interviews and questionnaires is predominant, there is also substantial reliance on secondary data sources such as literature reviews and expert opinions. This balance ensures that studies are grounded in current industry practices and informed by the broader academic discourse. The pie chart represents researchers' varied approaches to gathering data on sustainable packaging materials.

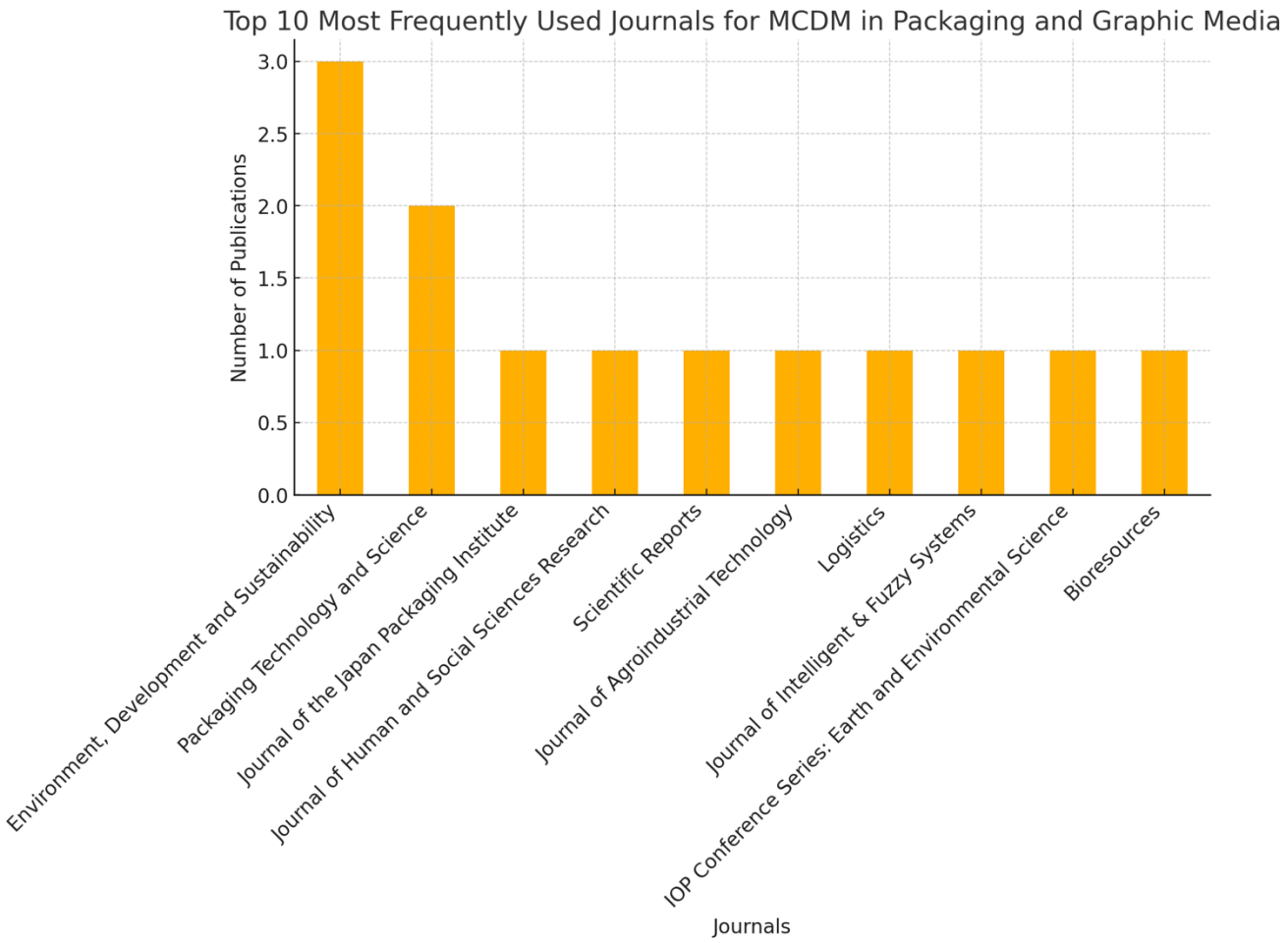

Figure 3. The Most Frequently Used Journals for Publications

The bar chart highlights the two most frequently used journals for publications on sustainable packaging materials. "Environment, Development and Sustainability" leads with three publications, indicating its significant role in this research area. This journal's focus on sustainability issues makes it a popular choice for researchers to publish their findings on sustainable packaging materials.

"Packaging Technology and Science" follows with two publications showcasing its relevance. This journal's emphasis on technological advancements and scientific research in packaging aligns well with studies on sustainable packaging solutions.

The concentration of publications in these two journals suggests they are key platforms for disseminating research on sustainable packaging materials. Researchers may prefer these journals due to their specialized focus and wide readership within the sustainability and packaging communities.

The chart reflects the importance of selecting appropriate journals for publishing research findings. It also highlights these journals' impact in advancing knowledge and promoting best practices in sustainable packaging materials.

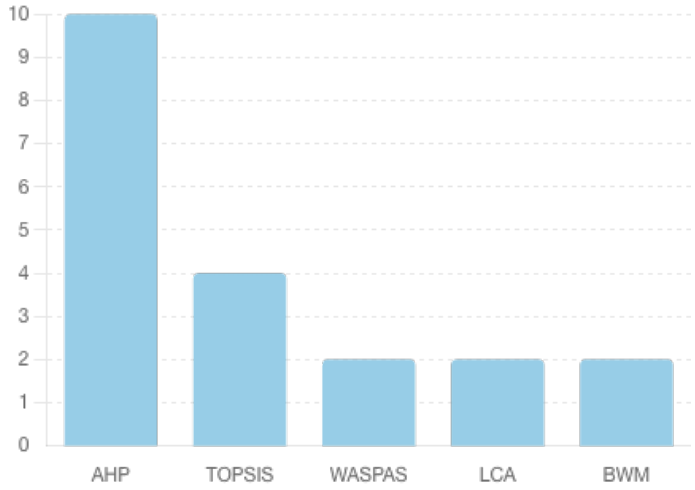

Figure 4. The Most Frequently Used MCDM (Multi-Criteria Decision-Making) Methods In Sustainable Packaging Material Studies

The bar chart displays the top five most frequently used Multi-Criteria Decision-Making (MCDM) methods in studies focused on sustainable packaging materials. The Analytic Hierarchy Process (AHP) is the most frequently utilized method in 10 studies. This highlights AHP's robust framework for structuring complex decision-making problems and its widespread acceptance among researchers.

TOPSIS is the second most common method, and it has been used in four studies. Its ability to rank alternatives based on their proximity to an ideal solution makes it popular for evaluating multiple criteria in packaging decisions. WASPAS and LCA appear in three studies, indicating their significant roles in integrating various decision-making criteria and conducting lifecycle assessments.

The fifth most frequently used method is BWM, appearing in two studies. This method's ability to handle decision-making problems by comparing alternatives with the best and worst criteria further underscores its relevance in sustainable packaging research.

These top five methods reflect the diversity and adaptability of MCDM techniques in addressing the complexities of sustainable packaging material selection. Each method offers unique strengths, whether it's through hierarchical structuring, proximity analysis, or lifecycle assessment, providing researchers with a comprehensive toolkit for making informed decisions.

Overall, the chart underscores the importance of these MCDM methods in advancing the field of sustainable packaging, showcasing their effectiveness in tackling various challenges and contributing to more sustainable practices.

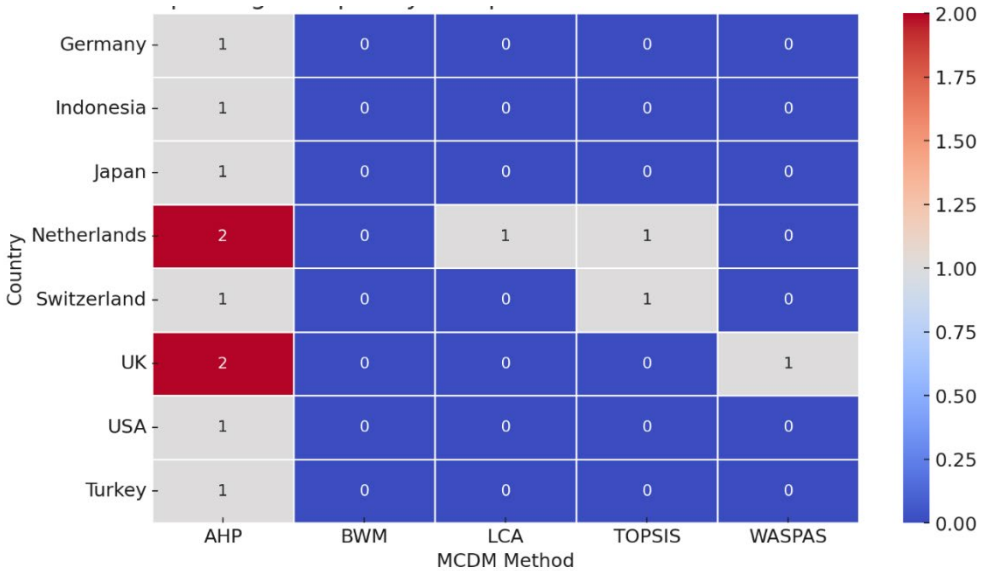

Figure 5. The Usage Frequency of Prominent MCDM Methods Across Different Countries

The heatmap offers a clear and insightful visualization of how frequently the top five MCDM (Multi-Criteria Decision-Making) methods are used across different countries. It highlights regional preferences and research trends, helping us understand which methods are favored in various parts of the world. The countries listed on the y-axis include Germany, Indonesia, Japan, the Netherlands, Switzerland, the UK, and the USA. At the same time, the x-axis displays the MCDM methods: AHP, BWM, LCA, TOPSIS, and WASPAS. The color intensity represents how often each method is used, with darker shades indicating higher usage.

Germany shows a preference for TOPSIS, which is used in one study. This suggests that German researchers value TOPSIS's ability to rank alternatives based on their closeness to an ideal solution. Other methods like AHP, BWM, LCA, and WASPAS don't appear in German studies, indicating a more focused approach. Indonesia has used AHP in one study, reflecting a selective but strategic choice. AHP is known for its ability to handle complex decision-making problems, making it a reliable choice for Indonesian researchers. Japan demonstrates a balanced approach, using AHP and LCA in one study each. This shows that Japanese researchers are equally interested in hierarchical decision-making and assessing the environmental impacts of packaging materials. The Netherlands stands out for its diverse use of MCDM methods. Researchers here have used AHP in two studies, TOPSIS in two studies, and LCA and WASPAS in one study each. This variety suggests a comprehensive and flexible approach to evaluating sustainable packaging materials, addressing multiple aspects of decision-making. Switzerland also shows a varied but focused application of methods, with AHP used in two studies and TOPSIS in one. Swiss researchers value structured decision-making frameworks and effective methods that rank alternatives.

The UK leads in methodological diversity, using AHP in three studies, BWM in two, and WASPAS in one. This extensive use of different methods highlights the UK's commitment to a thorough and multi-faceted approach to decision-making in sustainable packaging. AHP (Analytic Hierarchy Process) emerges as the most widely used method across the countries, particularly in the UK, the Netherlands, and Switzerland. Its popularity stems from its ability to break down complex problems into manageable parts, making it a go-to tool for researchers tackling sustainability challenges. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is notably used in the Netherlands and Germany. The Netherlands' use of TOPSIS in two studies reflects its importance in ranking alternatives, while Germany's single study shows a selective but meaningful application. BWM (Best Worst Method) and WASPAS are less common but still play important roles. The UK is the only country using BWM in two studies, showcasing its unique approach. WASPAS appears in studies from the Netherlands and the UK, each with one study indicating its niche but valuable role in decision-making. LCA (Life Cycle Assessment) is prominently used in Japan and the Netherlands, emphasizing its importance in evaluating the environmental impacts of packaging materials. Japan's single study and the Netherlands' one study using LCA demonstrate a focused effort to understand lifecycle impacts. The UK stands out for its methodological diversity, using AHP, BWM, and WASPAS across multiple studies. This suggests a comprehensive and well-rounded approach to decision-making, incorporating various perspectives and criteria.

Overall, the heatmap provides a valuable snapshot of global trends in sustainable packaging research. It reveals how countries prioritize specific methods based on their unique research goals and environmental policies. By visualizing these patterns, the heatmap helps us better understand the global landscape of MCDM applications in sustainable packaging.

5. Conclusion

The results of this study demonstrate that Multi-Criteria Decision Making (MCDM) techniques can be effectively utilized in the packaging and graphic media sectors. The reviewed literature indicates that MCDM techniques have been successfully applied to solve various problems in these sectors, leading to more efficient decision-making processes.

Techniques such as the Analytic Hierarchy Process (AHP), TOPSIS, and VIKOR are frequently used and have proven effective in addressing issues like material selection and design optimization. The studies provide detailed insights into data collection and analysis processes, showcasing how MCDM techniques can be effectively applied.

The findings suggest that MCDM techniques can significantly improve packaging and graphic media decision-making processes, contributing valuable insights for sectoral applications. Additionally, the study offers important recommendations for future research. This way, decision-making processes in the packaging and graphic media sectors can be more efficient and sustainable.

In conclusion, this study provides a comprehensive analysis of MCDM applications in the packaging and graphic media sectors, highlighting the potential and contributions of these techniques in enhancing decision-making processes. Continued research in this field will further aid in optimizing and advancing sectoral practices.

6. Discussion

Analyzing Multi-Criteria Decision Making (MCDM) techniques in the packaging and graphic media reveals several important insights and implications for academic research and industry practice. Firstly, it highlights the growing importance of sustainability in decision-making processes as companies increasingly seek eco-friendly and cost-effective packaging solutions. The study underscores the need for a more systematic approach to evaluating and comparing different MCDM methods, as current applications often lack a comprehensive framework for assessing their effectiveness. Additionally, integrating advanced technologies, such as artificial intelligence and machine learning, with MCDM models presents a

promising avenue for enhancing decision-making efficiency and accuracy. This research also identifies key areas for future exploration, including developing hybrid MCDM models that combine traditional decision-making techniques with innovative technologies to address complex challenges in the packaging and graphic media industries. By providing a structured evaluation of existing methodologies and proposing new directions for research, this study aims to bridge the gap between theoretical advancements and practical applications, ultimately contributing to more informed and sustainable decision-making in these sectors.

6.1 Diversity and Flexibility of MCDM Techniques

The frequent use of various MCDM techniques such as AHP, TOPSIS, and VIKOR underscores the flexibility and adaptability of these methods to different types of decision-making problems within the packaging and graphic media sectors. Each technique offers unique strengths and can be tailored to specific needs, whether material selection, design optimization, or other complex decision-making scenarios. This diversity suggests that there is no one-size-fits-all approach, and the specific context and criteria of the problem should guide the choice of technique.

6.2 Effectiveness in Enhancing Decision-Making Processes

The studies reviewed demonstrate that MCDM techniques are effective in improving decision-making processes. For instance, AHP has been widely adopted due to its robust framework for handling hierarchical decision problems. At the same time, TOPSIS is valued for its ability to rank alternatives based on their closeness to an ideal solution. These techniques have led to more informed and rational decisions, resulting in cost savings, improved product quality, and enhanced packaging and graphic media sustainability.

6.3 Global Trends and Regional Preferences

The heatmap analysis highlights significant regional preferences in the application of MCDM methods. For example, AHP is predominantly used in the UK, Netherlands, and Switzerland, indicating a strong preference for this method in these regions. The variation in method usage across countries reflects different research focuses and priorities, which could influence local environmental policies, research infrastructure, and industry needs. Understanding these regional trends can help tailor future research and application efforts to align with local contexts.

6.4 Challenges and Future Directions

Despite the demonstrated benefits of MCDM techniques, several challenges need to be addressed to enhance their application further. One major challenge is the complexity of the data collection and analysis process, which can be resource-intensive. Additionally, integrating MCDM with other decision-making tools and technologies, such as artificial intelligence and machine learning, presents future research opportunities. This integration could lead to more advanced and automated decision-making systems that handle larger datasets and more complex criteria.

6.5 Implications for Industry and Academia

For industry practitioners, the findings of this study provide valuable insights into how MCDM techniques can be applied to improve decision-making processes. Packaging and graphic media companies can achieve better efficiency, quality, and sustainability outcomes by adopting these methods. For academics, this study highlights the need for continued research into the development and refinement of MCDM techniques and their application to emerging challenges in these sectors.

6.6 Comparative Evaluation of Underutilized MCDM Methods and Literature Gaps

Existing studies on MCDM applications in packaging and graphic media have primarily focused on material selection and general sustainability assessments. For example, Brans and Vincke (1985) introduced the PROMETHEE method for ranking alternatives in multi-criteria decision-making, which has been widely applied in supply chain optimization but remains underutilized in packaging decisions, despite its potential for handling complex criteria and trade-offs in sustainable material selection [45]. Similarly, Roy (1968) developed the ELECTRE method, which has proven effective in industrial decision-making but has not been extensively adapted for graphical media selection [46].

In contrast, this study systematically compares multiple MCDM techniques within the packaging and graphic media sectors, including AHP, TOPSIS, and VIKOR, providing an in-depth evaluation of their strengths and limitations. Unlike Zavadskas et al. (2012), who introduced the weighted sum product assessment (WASPAS) method primarily for structural material selection and construction management [47], this research expands the scope by incorporating additional criteria such as cost-efficiency, consumer perception, and regulatory compliance. By conducting a structured comparative analysis, this study not only bridges the gap in the literature but also provides a practical framework for industry professionals to select the most suitable MCDM method based on specific project requirements.

6.7 Recommendations

Based on the findings of this study, several recommendations are proposed to enhance the effective use of Multi-Criteria Decision Making (MCDM) techniques in the packaging and graphic media sectors. First, increasing awareness and training on MCDM techniques for industry professionals is essential. Integration of MCDM with artificial intelligence can lead to

more efficient decision-making processes. Practical applications of MCDM techniques in material selection and design optimization should be encouraged. Further academic research is needed to explore and refine these techniques. Standardizing data collection and analysis processes will improve the reliability of MCDM applications. Companies should leverage modern data analytics tools to optimize their decision-making. International collaborations can help share best practices and innovative approaches. Developing new MCDM methods tailored to specific industry needs is crucial. Finally, continuous improvement of existing MCDM techniques will ensure they remain relevant and effective in addressing emerging challenges.

References

[1] L. Azzabi, D. Azzabi, and A. Kobi, *The Multi-Criteria Approach For Decision Support.* International Series in Operations Research and Management Science, 2020.

[2] M. Cinelli, S. R. Coles, and K. Kirwan, "Analysis of multi-criteria decision-making methods and their impacts on sustainability assessment indices," Journal of Cleaner Production, vol. 248, pp. 119-198, 2020.

[3] K. Govindan, S. Rajendran, J. Sarkis, and P. Murugesan, "Multi-criteria decision making approaches for green supplier evaluation and selection: a literature review," Journal of Cleaner Production, vol. 98, pp. 68, 2015.

[4] A. Mardani, A. Jusoh, K. M. Nor, Z. Khalifah, N. Zakwan, and A. Valipour, "Multiple criteria decision-making techniques and their applications – A review of the literature from 2000 to 2014," Economic Research-Ekonomska Istraživanja, vol. 28, no. 1, pp. 516-571, 2015.

[5] M. Stojčić, E.K. Zavadskas, D. Pamučar, Z. Stević, and A. Mardani, "Application of MCDM methods in sustainability engineering: A literature review 2008–2018," Symmetry, 11(3), 350, 2019.

[6] J. P. Brans and P. Vincke, "A preference ranking organisation method: The PROMETHEE method for multiple criteria decision-making," Management Science, vol. 31, no. 6, pp. 647-656, 1985.

[7] B. Roy, "Classement et choix en présence de points de vue multiples: La méthode ELECTRE," Revue Française d'Informatique et de Recherche Opérationnelle, vol. 2, no. 8, pp. 57-75, 1968.

[8] E. K. Zavadskas, Z. Turskis, J. Antucheviciene, and A. Zakarevicius, "Optimization of weighted aggregated sum product assessment," Elektronika ir Elektrotechnika, vol. 122, no. 6, pp. 3-6, 2012.

[9] J. R. Mendoza, "Application of MCDM methods in environmental sustainability: A review," Environmental Impact Assessment Review, vol. 45, pp. 1-12, 2018.

[10] K. Govindan, S. Rajendran, J. Sarkis, and P. Murugesan, "Multi-criteria decision making approaches for green supplier evaluation and selection: a literature review," Journal of Cleaner Production, vol. 98, pp. 73, 2015.

[11] M. Stojčić, E.K. Zavadskas, D. Pamučar, Z. Stević, and A. Mardani, "Application of MCDM methods in sustainability engineering: A literature review," Sustainability, vol. 11, no. 13, p. 3506, 2019.

[12] J. R. Figueira, S. Greco, and M. Ehrgott, Multiple Criteria Decision Analysis: State of the Art Surveys. Springer, 2016.

[13] R. K. Dhurkari, "MCDM methods: Practical difficulties and future directions for improvement," RAIRO-Operations Research, 56(4), 2221-2233, 2022.

[14] P. Kotler and K. L. Keller, Marketing Management, 15th ed., Pearson, 2016.

[15] L. L. Garber and E. M. Hyatt, "The role of package color in consumer purchase consideration and choice," Journal of Marketing Theory and Practice, vol. 11, no. 2, pp. 19-28, 2003.

[16] D. A. Aaker, Building Strong Brands, Simon and Schuster, 2010.

[17] D. Elkhattat, and M. Medhat, "Creativity in packaging design as a competitive promotional tool," Information Sciences Letters, 11(1), 135-145, 2022.

[18] H. Kipphan, (Ed.),. *Handbook of print media: technologies and production methods,* Springer Science & Business Media, 2001.

[19] J. W. Palmer and M. L. Markus, "The challenges of sustainable packaging: A review of industry practices and regulatory requirements," Journal of Cleaner Production, vol. 265, p. 121702, 2020.

[20] K. L. Keller and P. Kotler, Marketing Management, 16th ed., Pearson, 2021.

[21] A. M. Bocken, S. W. Short, P. Rana, and S. Evans, "A literature and practice review to develop sustainable business model archetypes," Journal of Cleaner Production, vol. 65, pp. 42-56, 2014.

[22] R. Verghese, H. Lewis, and K. Fitzpatrick, Packaging for Sustainability, Springer, 2012.

[23] L. A. Al-Kindi, and Z. Al-Baldawi, "Green packaging for durable engineering products in Iraqi markets. In IOP Conference Series: Earth and Environmental Science," Vol. 779, No. 1, p. 012004, IOP Publishing, 2021.

[24] Albayrak, Ö. K. (2021). A hybrid multi-criteria decision-making method proposal for the solution of the packaging supplier selection problem. İnsan ve Toplum Bilimleri Araştırmaları Dergisi, 10(2), 1118-1139.

[25] L. Anojkumar, M. Ilangkumaran, and V. Sasirekha, Comparative analysis of MCDM methods for pipe material selection in sugar industry. Expert systems with applications, 41(6), 2964-2980, 2014.

[26] C. Horvath, and L. Koltai, "Key recommendations for the printed packaging in the circular economy," In 1st International Conference on Circular Packaging (CPC), Ljubljana, Slovenia, pp. 26-27, 2019.

[27] M.M. Da Cruz, R.G.G Caiado, and R.S. Santos, "Industrial Packaging Performance Indicator Using a Group Multicriteria Approach: An Automaker Reverse Operations Case," Logistics, 6(3), 58, 2022.

[28] M.P. Desole, A. Gisario, L. Fedele, and M. Barletta, "Life Cycle Assessment (LCA) and Multi Criteria Decision Analysis (MCDA) of eco-friendly packaging for dairy products and fourth range," Procedia CIRP, 122, 927-932, 2024.

[29] Elkhattat, D., & Medhat, M. (2022). Creativity in packaging design as a competitive promotional tool. Information Sciences Letters, 11(1), 135-145.

[30] B. Gulsun, and P. Mic, "An integrated fuzzy multi criteria decision making method for sustainable (green) packaging materials selection: An application in Turkey," FEB Fresenius Environmental Bulletin, 2653, 2020.

[31] W. Habsar, T. Djatna, F. Udin, and Y. Arkeman, "A Multi-Criteria decision-making approach using AHP for pudak packaging supplier selection," Jurnal Teknologi Industri Pertanian, 32(2), 197-203, 2022.

[32] L. Huo, and K. Saito, "Multi-criteria evaluation techniques for sustainable packaging system," Japan Packaging Institute, 17(3), 167-178, 2008.

[33] J. Jeon, S. Krishnan, T. Manirathinam, S. Narayanamoorthy, M. Nazir Ahmad, M. Ferrara, and A. Ahmadian, "An innovative probabilistic hesitant fuzzy set MCDM perspective for selecting flexible packaging bags after the prohibition on single-use plastics," Scientific Reports, 13(1), 10206, 2023.

[34] H.Y. Kang, A.H. Lee, and C.Y. Yang, "A fuzzy ANP model for supplier selection as applied to IC packaging," Journal of Intelligent Manufacturing, 23, 1477-1488, 2012.

[35] L. Ling, R. Anping, and X. Di, "Proposal of a hybrid decision-making framework for the prioritization of express packaging recycling patterns," Environment, Development and Sustainability, 25(3), 2610-2647, 2023.

[36] A. Mahajan, I. Singh, and N. Arora, "An integrated multi-criteria decision-making framework for the selection of sustainable, biodegradable polymer for food packaging applications," Environment, Development and Sustainability, 26(4), 8399-8420, 2024

[37] S. Pongpimol, Y.F. Badir, B.L. Erik, V. Sukhotu, "A multi-criteria assessment of alternative sustainable solid waste management of flexible packaging," Management of Environmental Quality: An International Journal, 31(1), 201-222, 2020.

[38] B. Porto De Lima, A.F. Da Silva, and F.A.S. Marins, " New hybrid AHP-QFD-PROMETHEE decision-making support method in the hesitant fuzzy environment: an application in packaging design selection," Journal of Intelligent & Fuzzy Systems, 42(4), 2881-2897, 2022.

[39] H.G. Resat, and B.Unsal, "A novel multi-objective optimization approach for sustainable supply chain: A case study in packaging industry," Sustainable production and consumption, 20, 29-39, 2019.

[40] J. Rezaei, A. Papakonstantinou, L. Tavasszy, U. Pesch, U., A. Kana, "Sustainable product-package design in a food supply chain: A multi-criteria life cycle approach," Packaging Technology and Science, 32(2), 85-101, 2019.

[41] H.N. Salwa, S.M. Sapuan, M.T. Mastura, and M.Y.M. Zuhri, "Application of Shannon's entropy-analytic hierarchy process (AHP) for the selection of the most suitable starch as matrix in green biocomposites for takeout food packaging design," BioResources, 15(2), 4065-4088, 2020.

[42] N. Silva, and D. Blumberga, "Why biopolymer packaging materials are better," Environmental and Climate Technologies, 23(2), 366-384, 2019.

[43] A. Singh, and S.K. Malik, "Major MCDM Techniques and their application-A Review," IOSR Journal of Engineering, 4(5), 15-25, 2014.

[44] J. Zambujal-Oliveira, and C. Fernandes, "The contribution of sustainable packaging to the circular food supply chain," Packaging Technology and Science, 37(5), 443-456, 2024.

[45] J. P. Brans, and P. Vincke, "A preference ranking organisation method: The PROMETHEE method for multiple criteria decision-making," Management Science, 31(6), 647-656, 1985.

[46] B. Roy, "Classement et choix en présence de points de vue multiples: La méthode ELECTRE," Revue Française d'Informatique et de Recherche Opérationnelle, 2(8), 57-75, 1968.

[47] E. K. Zavadskas, Z. Turskis, J. Antucheviciene, and A. Zakarevicius, "Optimization of weighted aggregated sum product assessment," Elektronika ir Elektrotechnika, 122(6), 3-6, 2012.

Author Note:

This article is a result of an independent research study conducted by the author. Special thanks to colleagues and professionals who provided feedback during the evaluation phase of the study.

Conflict of Interest Disclosure:

No potential conflict of interest was declared by the author.

Artificial Intelligence Statement:

Artificial intelligence tools were used to support the writing process of this article, particularly for language editing and content structuring. However, all ideas, analyses, and conclusions presented are original and solely belong to the author.

Plagiarism Statement:

This article has been scanned by iThenticate and found to be free of plagiarism.