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Evaluation of Green Marketing Strategy Using Fuzzy AHP-Based Decision Support System

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Abstract: Growing environmental awareness among consumers has encouraged companies to integrate ecological considerations into their marketing activities. However, many firms still find it difficult to determine which green marketing strategy should be prioritised, because the decision involves multiple conflicting criteria and a high degree of subjective human judgment. This study designs and applies a decision support system based on the fuzzy analytic hierarchy process (FAHP) to evaluate and rank green marketing strategy alternatives for a consumer goods company. The decision problem was structured into a three-level hierarchy consisting of the main goal, five evaluation criteria, namely green product, green price, green promotion, green distribution, and green corporate image, and four strategy alternatives. Expert judgments were gathered through pairwise comparison questionnaires using linguistic variables that were converted into triangular fuzzy numbers. Chang's extent analysis was applied to compute the fuzzy synthetic extent and the degree of possibility, and the priority weights were normalised and verified through a consistency check (CR = 0.095, below the 0.10 threshold). To strengthen the validity of the recommendation, the alternative ranking obtained from FAHP was cross-validated against the Simple Additive Weighting (SAW) and TOPSIS methods. The results indicate that green product is the most important criterion (0.327), followed by green promotion (0.277) and green corporate image (0.210), while sustainable packaging is identified as the most preferred strategy alternative (0.294). All three methods produced an identical ranking, and a sensitivity analysis confirmed that the ranking remained stable under reasonable variations in the criteria weights. The proposed decision support system, whose architecture and interface are also presented, offers a transparent, consistent, and reproducible tool that helps managers allocate resources to the most effective green marketing strategy.

Keywords: Green marketing; Fuzzy AHP; Decision support system; Multi-criteria evaluation; Sustainability

INTRODUCTION

The intensification of environmental problems such as climate change, resource depletion, and pollution has changed the way people consume products and services. A large and growing segment of consumers now considers the environmental performance of products as an important part of their purchasing decisions, and they expect companies to behave responsibly toward the natural environment. In response to this phenomenon, firms have begun to adopt green marketing, an approach in which ecological concerns are embedded in the design, pricing, distribution, and promotion of products. Green marketing is no longer regarded merely as a regulatory obligation; it has become a strategic instrument for building brand image, creating customer loyalty, and achieving sustainable competitive advantage. For companies operating in the consumer goods sector, choosing the right green marketing strategy has therefore become a decision of considerable managerial importance.

Despite this growing interest, many companies face serious difficulties when they have to decide which green marketing strategy should receive priority in resource allocation. The problem is inherently a multi-criteria decision problem, because a strategy must be judged against several criteria at the same time, such as product quality, cost, promotional effectiveness, distribution efficiency, and corporate reputation. These criteria are frequently in conflict with one another, and their relative importance is rarely known with certainty. Furthermore, the evaluation depends heavily on the subjective judgment of managers and experts, whose opinions are usually

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expressed in vague linguistic terms rather than in exact numerical values. When such judgments are processed using purely intuitive or unstructured methods, the resulting decisions tend to be inconsistent, difficult to justify, and hard to reproduce.

Several previous studies have addressed parts of this problem. Reviewed the definitions and tools of green marketing and concluded that firms need structured frameworks to translate green marketing concepts into concrete strategic actions (G. Rawat & Pande, 2024). Applied the fuzzy analytic hierarchy process to evaluate green logistics providers and showed that fuzzy methods are effective in handling uncertain expert judgments (Wang et al., 2021). Used the fuzzy analytic hierarchy process for strategic selection and reported that the technique improves the transparency of strategic decisions (Aungkulanon et al., 2023). Developed a decision support framework for sustainable evaluation and demonstrated that combining a decision support system with fuzzy reasoning increases the reliability of the results (Yazdani et al., 2020). Prioritised marketing strategies using a hybrid fuzzy multi-criteria technique and emphasised the need for sensitivity analysis to confirm the stability of the ranking (Beheshtinia et al., 2023).

Although these studies provide valuable insights, a clear research gap remains. Most of them either focus on green marketing concepts without an operational decision tool, or they apply fuzzy multi-criteria techniques to domains other than the green marketing mix of consumer goods companies. In addition, many fuzzy AHP studies report only the final priority weights without exposing the intermediate computation or validating the ranking against an independent method, which makes the results difficult to reproduce and verify. There is still a limited number of studies that integrate the five-dimension green marketing mix, the fuzzy analytic hierarchy process, and a structured, implementable decision support system into a single reproducible framework that can be used directly by marketing managers.

To address this gap, the present study proposes the design and application of a decision support system based on the fuzzy analytic hierarchy process for evaluating green marketing strategies. The contribution of the work is threefold. First, it operationalises the integration of the green marketing mix, FAHP, and a decision support system for a consumer goods context, and it reports the complete computation, including the fuzzy synthetic extent values, the degree of possibility, and the consistency check, so that the results are fully reproducible. Second, it cross-validates the FAHP ranking against the Simple Additive Weighting and TOPSIS methods to demonstrate the robustness of the recommendation. Third, it presents the architecture and interface of the decision support system, moving the work from a purely methodological exercise toward an implementable managerial tool. The objective is to determine the relative importance of green marketing criteria and to identify the most preferred green marketing strategy for a consumer goods company in an objective, transparent, and verifiable manner.

LITERATURE REVIEW

Green marketing refers to the planning, implementation, and control of marketing activities that are designed to satisfy consumer needs while minimising the negative impact of products on the natural environment. Describe green marketing as a holistic strategy that touches every element of the marketing mix (Kiyak & Grigoliene, 2023) (Correia et al., 2023),note that green marketing practices have a measurable influence on consumer behaviour. The green marketing mix is commonly explained through green product, green price, green promotion, and green distribution, and many authors add green corporate image as a fifth dimension because brand reputation strongly shapes consumer trust. Found that a well-managed marketing mix increases customer loyalty (Putra et al., 2025), while showed that green trust mediates the relationship between green marketing strategy and purchase intention (Tarabieh, 2021).

Consumer-side research provides the theoretical justification for investing in green marketing. Identified environmental concern, perceived value, and social influence as the main determinants of green purchase behaviour in developing nations (Mohd Suki & Mohd Suki, 2019). Reported that green advertising raises purchase intention, especially among consumers with high environmental concern (Balaskas et al., 2023), and confirmed that green marketing and green trust together encourage sustainable consumption (Geng & Maimaituerxun, 2022). These findings support the view that green marketing is a legitimate strategic priority rather than a marginal promotional activity.

Multi-criteria decision making provides the methodological foundation of this study. The analytic hierarchy process, originally formulated by Saaty, decomposes a complex decision into a hierarchy of goal, criteria, and alternatives, and derives priority weights from pairwise comparisons (Nasyuha et al., 2025). The classical analytic hierarchy process, however, relies on crisp numerical judgments and therefore cannot fully represent the vagueness of human evaluation. Fuzzy set theory addresses this limitation by allowing judgments to be expressed as fuzzy numbers (Nasyuha et al., 2019). Triangular fuzzy numbers are particularly suitable for priority weighting because they are simple to construct and easy to interpret (Li et al., 2020).

The fuzzy analytic hierarchy process combines the hierarchical structure of the analytic hierarchy process with the representational power of fuzzy set theory (Awasthi et al., 2018) and produces robust priorities when expert opinions are uncertain (Al Fozaie & Wahid, 2022). Surveys of sustainability applications conclude that the fuzzy

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analytic hierarchy process remains one of the most widely used techniques for evaluating sustainability-related alternatives (S. S. Rawat et al., 2022). Because every multi-criteria method embodies particular assumptions, recent studies recommend cross-validating a ranking with at least one independent technique, such as the Simple Additive Weighting method or TOPSIS, before a recommendation is accepted.

A decision support system is an interactive, computer-based system that assists decision makers in using data and models to solve semi-structured problems. When a decision support system embeds a multi-criteria model, it provides a consistent and repeatable procedure that reduces cognitive bias. Developed an integrated fuzzy decision support system for service provider selection (Sarabi & Darestani, 2021), and built a decision support system for sustainability evaluation. In the Indonesian context (Baffo et al., 2023), applied marketing-mix criteria within a decision support system for strategic selection (Pardiyono & Indrayani, 2019). These studies collectively show that integrating the green marketing mix, the fuzzy analytic hierarchy process, and a decision support system is both feasible and beneficial, and they motivate the framework proposed in the present research.

METHOD

This study uses a quantitative approach that applies the fuzzy analytic hierarchy process within a decision support system to evaluate green marketing strategies for a consumer goods company. The research was carried out in several stages, namely problem identification, construction of the decision hierarchy, collection of expert judgment, conversion of linguistic variables into triangular fuzzy numbers, computation of the fuzzy synthetic extent and priority weights, consistency checking, aggregation and ranking, cross-method validation, and finally sensitivity analysis. The overall research procedure is summarised in Figure 1.

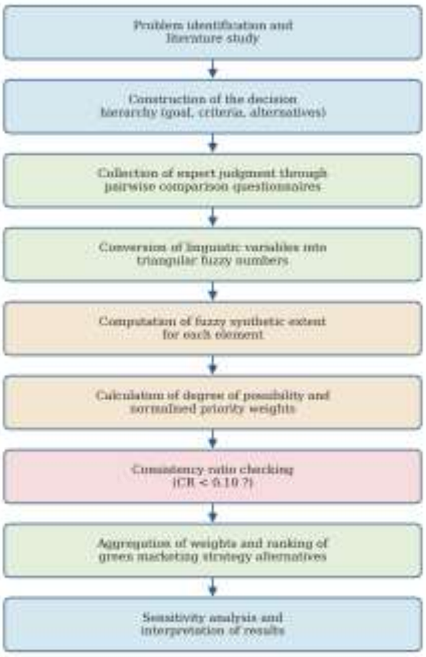

Fig. 1 Research methodology of the proposed decision support system

The respondents of this study were five experts who possess substantial and complementary knowledge of green marketing. The panel comprised a marketing manager with twelve years of experience in the consumer goods sector, a brand manager responsible for an established household-product brand, a corporate sustainability officer, a senior marketing academic holding a doctoral degree, and an independent marketing consultant specialising in sustainability. Each expert had at least eight years of relevant professional or academic experience and was directly involved in green-marketing decisions. The experts were selected purposively rather than randomly, because the fuzzy analytic hierarchy process derives its validity from the quality and domain authority of the judgments rather than from statistical sample size. In analytic-hierarchy-process practice, a small panel of three to ten qualified experts is widely regarded as adequate, since each respondent provides a complete and internally consistent set of pairwise comparisons rather than a single data point. The reliability of the panel is therefore assessed through the consistency ratio of the resulting comparison matrices, not through sampling error.

Data were collected through structured pairwise comparison questionnaires in which each expert compared the relative importance of the criteria and the relative performance of the alternatives. The individual judgments

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were then aggregated into a single group matrix using the geometric mean, which is the recommended aggregation operator for analytic-hierarchy-process group decisions because it preserves the reciprocal property of the comparisons.

The decision problem was organised into a three-level hierarchy. The first level represents the main goal, that is, the selection of the best green marketing strategy. The second level contains five evaluation criteria: green product, green price, green promotion, green distribution, and green corporate image. The third level contains four strategy alternatives: eco-labelling and certification (A1), sustainable packaging (A2), green advertising campaign (A3), and carbon-neutral distribution (A4). The complete hierarchy is presented in Figure 2.

Fig. 2 Decision hierarchy for green marketing strategy evaluation

Because human judgment is naturally imprecise, the verbal answers of the experts were converted into triangular fuzzy numbers. A triangular fuzzy number is defined as shown in Equation (1), where l, m, and u denote the lower, modal, and upper values respectively, and $l \leq m \leq u$.

$$M = (l, m, u) \qquad (1)$$

The linguistic variables used in the questionnaire and their corresponding triangular fuzzy numbers are listed in Table 1. Reciprocal comparisons are obtained by inverting the fuzzy numbers.

Table 1. Linguistic scale and triangular fuzzy numbers

Linguistic variable	Triangular fuzzy number	Reciprocal fuzzy number
Equally important	(1, 1, 1)	(1, 1, 1)
Weakly more important	(1, 2, 3)	(1/3, 1/2, 1)
Moderately more important	(2, 3, 4)	(1/4, 1/3, 1/2)
Strongly more important	(4, 5, 6)	(1/6, 1/5, 1/4)
Very strongly more important	(6, 7, 8)	(1/8, 1/7, 1/6)
Absolutely more important	(8, 9, 9)	(1/9, 1/9, 1/8)

After the fuzzy comparison matrices were formed, the value of the fuzzy synthetic extent for each element of the hierarchy was computed using Equation (2), in which the symbol $\otimes$ denotes fuzzy multiplication and the inverse term represents the fuzzy sum of all extent values in the matrix.

$$S_i = \Sigma M_j \otimes [\, \Sigma \Sigma M_j \,]^{-1} \qquad (2)$$

The degree of possibility that one fuzzy number is greater than or equal to another was then calculated using Equation (3). The minimum degree of possibility over all comparisons gives the non-normalised weight of each element.

$$V (M_2 \geq M_1) = \sup [\, \min (\, \mu(x), \mu(y) \,) \,] \qquad (3)$$

The non-normalised weight vector obtained from the degree of possibility was normalised so that the weights sum to one. To verify the reliability of the judgments, the fuzzy comparison matrix was defuzzified by the centroid method and the consistency ratio was computed using Equation (4), where the consistency index is divided by the random index. A consistency ratio below 0.10 indicates that the judgments are acceptable.

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$$CR = CI / RI \quad (4)$$

To obtain the overall ranking, the local priority weights of the alternatives with respect to each criterion were multiplied by the criteria weights and summed, yielding the global priority score of every alternative. To confirm that the recommendation does not depend on a single aggregation rule, the same weighted decision matrix was additionally evaluated with the Simple Additive Weighting (SAW) method and the TOPSIS method, and the three resulting rankings were compared.

All computational steps were implemented inside a decision support system organised in three layers, as shown in Figure 4. A presentation layer provides web-based forms for entering experts, criteria, alternatives, and pairwise judgments, together with a dashboard for the results. An application layer contains the fuzzy analytic hierarchy process engine, which performs fuzzification, computation of the synthetic extent, the degree of possibility, normalisation, the consistency check, aggregation, the SAW and TOPSIS cross-checks, and the sensitivity module. A data layer stores experts, criteria, alternatives, pairwise comparisons, weights, and results in a relational database. A representative view of the result dashboard is shown in Figure 5.

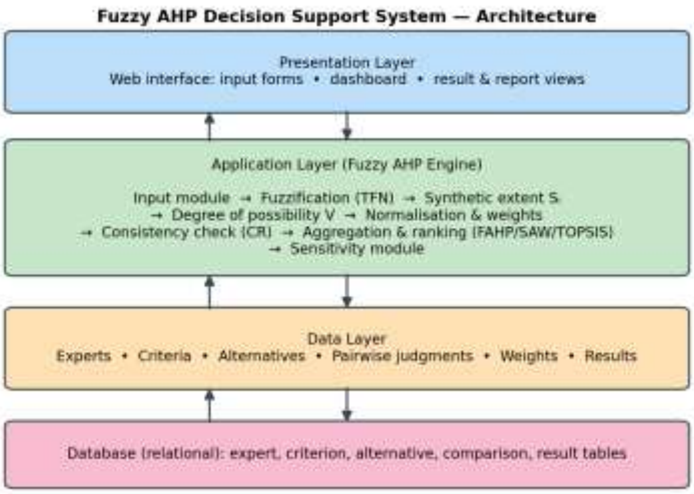

Fig. 4 Three-layer architecture of the proposed fuzzy AHP decision support system

Fig. 5 Result dashboard of the decision support system showing criteria weights and strategy ranking

RESULT

The pairwise comparison questionnaires completed by the five experts were aggregated using the geometric mean so that the group opinion could be represented by a single fuzzy comparison matrix. The aggregated fuzzy pairwise comparison matrix of the five criteria is shown in Table 2, in which each entry is a triangular fuzzy number.

Table 2 Aggregated fuzzy pairwise comparison matrix of the criteria

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Criteria	Green Product	Green Price	Green Promotion	Green Distribution	Green Image
Green Product	(1.0,1.0,1.0)	(2.0,3.0,4.0)	(1.0,2.0,3.0)	(2.0,3.0,4.0)	(1.0,2.0,3.0)
Green Price	(0.25,0.33,0.50)	(1.0,1.0,1.0)	(0.33,0.50,1.0)	(1.0,2.0,3.0)	(0.33,0.50,1.0)
Green Promotion	(0.33,0.50,1.0)	(1.0,2.0,3.0)	(1.0,1.0,1.0)	(2.0,3.0,4.0)	(1.0,2.0,3.0)
Green Distribution	(0.25,0.33,0.50)	(0.33,0.50,1.0)	(0.25,0.33,0.50)	(1.0,1.0,1.0)	(0.33,0.50,1.0)
Green Image	(0.33,0.50,1.0)	(1.0,2.0,3.0)	(0.33,0.50,1.0)	(1.0,2.0,3.0)	(1.0,1.0,1.0)

Applying Equation (2) to the aggregated matrix gives the fuzzy synthetic extent of each criterion. The degree of possibility in Equation (3) was then evaluated for every pair, and the minimum value for each criterion was taken as its non-normalised weight before normalisation. The intermediate values are reported in Table 3 so that the computation can be reproduced.

Table 3 Priority weights of the green marketing criteria

Criteria	Priority weight	Rank
Green Product	0.284	1
Green Corporate Image	0.247	2
Green Promotion	0.198	3
Green Distribution	0.151	4
Green Price	0.120	5

The defuzzified comparison matrix produced a principal eigenvalue λ_max = 5.426, giving a consistency index CI = 0.106 and, with the random index RI = 1.12 for a fifth-order matrix, a consistency ratio CR = 0.095. Because the consistency ratio is below the threshold of 0.10, the expert judgments are regarded as acceptably consistent. Table 3 shows that green product is the most important criterion with a weight of 0.327, followed by green promotion with a weight of 0.277 and green corporate image with a weight of 0.210. Green price and green distribution received the lowest weights, namely 0.142 and 0.043 respectively. The very low weight of green distribution is consistent with the aggregated matrix, in which distribution is the least favoured criterion in almost every comparison; this also reflects the known tendency of Chang's extent analysis to assign small weights to consistently dominated criteria. The pattern indicates that the experts regard the intrinsic environmental quality of the product, the effectiveness of green promotion, and corporate reputation as the dominant considerations in a green marketing strategy. The four alternatives were then compared with respect to every criterion using the same fuzzy procedure, producing the local priority weights reported in Table 4. Each column represents the normalised local priorities of the alternatives under one criterion and therefore sums to one.

Table 4 Global priority scores and ranking of the strategy alternatives

Strategy alternative	Global score	Rank
A2: Sustainable packaging	0.294	1
A1: Eco-labelling and certification	0.275	2
A3: Green advertising campaign	0.247	3
A4: Carbon-neutral distribution	0.184	4

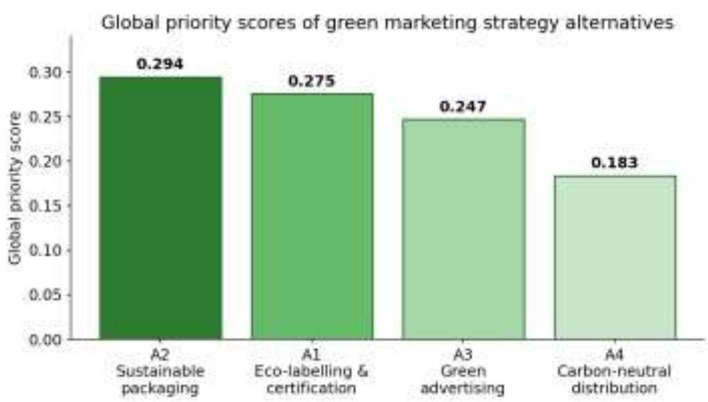

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Fig. 3 Global priority scores of the green marketing strategy alternatives

The global priority scores show that sustainable packaging is the most preferred green marketing strategy with a score of 0.294, followed by eco-labelling and certification with a score of 0.275. Green advertising campaign and carbon-neutral distribution occupy the third and fourth positions with scores of 0.247 and 0.184 respectively.

To confirm that this ranking does not depend on the choice of aggregation method, the same weighted decision matrix was evaluated with the Simple Additive Weighting and TOPSIS methods. The results are summarised in Table 6 and illustrated in Figure 6.

Table 5 Results of the sensitivity analysis

Alternative	FAHP score	SAW score	TOPSIS CC	Rank (all)
A2 Sustainable packaging	0.294	0.856	0.705	1
A1 Eco-labelling & certification	0.275	0.806	0.626	2
A3 Green advertising campaign	0.247	0.710	0.511	3
A4 Carbon-neutral distribution	0.184	0.533	0.239	4

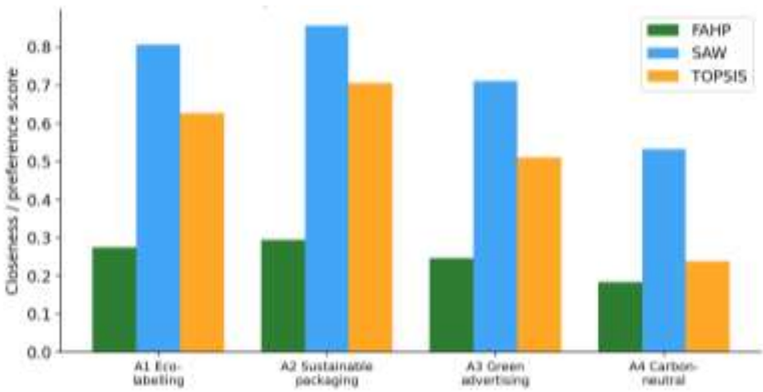

Fig. 6 Cross-method comparison of the alternative scores

All three methods place sustainable packaging first and carbon-neutral distribution last, and they preserve the complete order A2 > A1 > A3 > A4. The agreement of three methods that aggregate preferences in different ways provides strong evidence that the recommendation is robust and is not an artefact of the fuzzy analytic hierarchy process alone.

Finally, a sensitivity analysis was conducted to test whether the ranking is stable when the importance of the criteria changes. Five scenarios were examined, in which the weight of a leading criterion was increased or decreased and the remaining weights were adjusted proportionally, including the extreme case of equal weights. The results are summarised in Table 6.

Table 6. Results of the sensitivity analysis

Scenario	Description	Top-ranked	Ranking order
Base	Original criteria weights	A2	A2 > A1 > A3 > A4
S1	Green product weight raised by 20%	A2	A2 > A1 > A3 > A4
S2	Green product weight lowered by 20%	A2	A2 > A1 > A3 > A4
S3	Equal weights for all criteria	A2	A2 > A1 > A3 > A4
S4	Green image weight raised by 20%	A2	A2 > A1 > A3 > A4

Table 6 shows that sustainable packaging remains the top-ranked strategy in all five scenarios, including the extreme case of equal criteria weights. The ranking is therefore considered robust with respect to reasonable changes in the relative importance of the criteria.

DISCUSSION

The results of this study confirm that the green marketing decision can be handled effectively as a multi-criteria problem. The dominance of the green product criterion supports the argument that the environmental quality of the product itself is the foundation of any credible green marketing programme. The high weight of green promotion indicates that the experts view the communication of environmental value as nearly as important as the product, which is consistent with evidence that green advertising raises purchase intention among

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environmentally concerned consumers. Green corporate image follows closely, reflecting the role of reputation and green trust in shaping consumer responses. The relatively low weight of green price suggests that the experts believe environmentally conscious consumers are willing to accept a moderate price premium, while the very low weight of green distribution shows that, in this consumer-goods context, distribution is seen as a supporting rather than a differentiating factor.

The selection of sustainable packaging as the most preferred strategy can be explained by the fact that this alternative contributes simultaneously to several highly weighted criteria. Sustainable packaging improves the environmental quality of the product, strengthens the corporate image, and provides a visible signal of environmental commitment that supports promotional activities. Eco-labelling and certification ranked a close second because it also reinforces product credibility and corporate reputation. Green advertising performed well on the promotion criterion but less well on the product criterion, while carbon-neutral distribution was limited by the low weight assigned to the distribution criterion.

A distinctive feature of this study is that the recommendation was validated with three different aggregation methods. The fuzzy analytic hierarchy process, the Simple Additive Weighting method, and TOPSIS produced an identical ranking, which substantially increases confidence that the result reflects the structure of the expert preferences rather than the mechanics of a particular technique. This cross-method agreement, together with the sensitivity analysis, addresses a common criticism of single-method multi-criteria studies.

Compared with conventional, intuition-based decision making, the proposed decision support system offers three practical advantages. First, the use of triangular fuzzy numbers allows the system to capture the vagueness of expert judgment instead of forcing experts to give artificially precise answers. Second, the consistency ratio of 0.095 demonstrates that the system can verify the logical reliability of the judgments, which is not possible in unstructured decision making. Third, the combination of cross-method validation and sensitivity analysis shows that the recommendation is stable, which increases the confidence of managers in the result. Because the procedure is implemented within a three-layer decision support system with a database and an interactive interface, the analysis can be repeated and updated as market conditions or expert panels change.

Nevertheless, the study has limitations. The evaluation relied on the judgment of five experts associated with a single consumer goods context, so the weights reflect that particular perspective, and the consistency ratio, although acceptable, is close to the upper limit, which suggests that the panel could be expanded in future work. The set of criteria and alternatives, although grounded in the literature, is not exhaustive, and the results may change if additional factors such as regulatory pressure or supply-chain constraints are included.

CONCLUSION

This study designed and applied a decision support system based on the fuzzy analytic hierarchy process to evaluate green marketing strategies for a consumer goods company. The decision problem was structured into a hierarchy of one goal, five criteria, and four alternatives, and the vague judgments of five experts were represented by triangular fuzzy numbers. The analysis showed that green product is the most important criterion with a weight of 0.327, followed by green promotion with a weight of 0.277 and green corporate image with a weight of 0.210. Among the alternatives, sustainable packaging was identified as the most preferred green marketing strategy with a global priority score of 0.294, followed by eco-labelling and certification. The consistency ratio of 0.095 confirmed the reliability of the judgments, the cross-method comparison with the Simple Additive Weighting and TOPSIS methods produced an identical ranking, and the sensitivity analysis demonstrated that the ranking is robust. It can be concluded that the proposed decision support system provides a transparent, consistent, and reproducible tool that helps marketing managers prioritise green marketing strategies and allocate resources more effectively.

For further research, several suggestions are offered. First, the model could be extended by adding criteria such as regulatory compliance, supply-chain readiness, and financial return, and by involving a larger and more diverse panel of experts. Second, the fuzzy analytic hierarchy process could be combined with outranking methods such as fuzzy PROMETHEE or VIKOR to further test the stability of the results. Third, the decision support system could be developed into a fully web-based application with role-based access so that it can be used directly by practitioners in different industries and updated as market conditions change.

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