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A MULTI-CRITERIA DECISION-MAKING FRAMEWORK FOR EVALUATING THE CARBON FOOTPRINT AND SUSTAINABILITY PERFORMANCE OF DIGITAL MARKETING CHANNELS

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Abstract: Digital marketing has expanded rapidly, and with it the use of data-intensive advertising systems whose energy use and carbon emissions are rarely questioned. Sustainability now receives close attention in business and engineering, yet the environmental side of digital marketing channels has been studied very little. This study addresses that gap with a multi-criteria decision-making (MCDM) framework that evaluates digital marketing channels on both performance and sustainability. Objective weights from the CRITIC and MEREC methods are combined with WASPAS to rank five channels under several criteria. Besides the usual performance indicators (click-through rate, engagement, conversion, cost per click and return on investment), the model adds carbon footprint and energy consumption as proxy sustainability criteria. The decision matrix draws on benchmark values and computational energy coefficients reported in the literature, which gives a comparable dataset without any primary data collection. The framework rests on the Natural-Resource-Based View (NRBV) of the firm, which treats environmentally efficient capabilities as a source of competitive advantage. Adding the sustainability criteria changes the ranking and brings out the trade-off between marketing performance and environmental cost. The framework offers managers an objective tool for judging channels with sustainability in mind, and it links digital marketing analytics to environmental sustainability through an engineering-oriented model. Email Marketing obtained the highest overall score (1.000) and Display Advertising the lowest (0.490). The CRITIC and MEREC weightings produced the same ranking, confirmed by a Spearman rank correlation of rs = 1.000 (P<0.001), which points to a stable framework.

Keywords: Multi-criteria decision-making, Digital marketing, Sustainability, Carbon footprint, CRITIC, MEREC

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1. Introduction

Digitalization has changed how firms plan and assess their marketing. Channels such as social media, search engines and programmatic advertising are now central to reaching consumers, and they run on continuous data processing and cloud infrastructure. Because of this, firms tend to measure marketing through quantitative indicators: click-through rate, engagement, conversion and return on investment. What this view usually leaves out is the environmental cost of the infrastructure behind those numbers.

Digital technologies are far from environmentally neutral. de Vries-Gao (2025) shows that demand for data storage, real-time analytics and artificial intelligence has pushed up the energy needs of data centres sharply, while Liu and Fang (2025) link the growth of the digital economy to rising carbon emissions, which suggests that digitalization can carry costs that are easy to miss. For advertising in particular the footprint is not trivial; Pärssinen et al. (2018) and more recent industry analyses estimate that internet and ad-tech infrastructure account for several percent of global CO_2 output (Centre for Social Innovation, 2025). Findings of this kind have brought the sustainability of digital systems into question.

The idea of a digital carbon footprint has gained ground in recent years. Online advertising, data transmission and user interaction all generate indirect emissions through the computation behind them. These emissions are less visible than those of heavy industry, but they accumulate at scale. Thangam et al. (2024) point to data centres as a major driver of the footprint of digital services, and Caldeira et al. (2026) argue that this footprint needs to be measured and managed as part of any serious sustainability effort.

Even so, the environmental side of digital marketing has had little attention. Most digital marketing research stays with economic performance and user engagement and rarely folds sustainability into how performance is judged. A few recent studies have started to close this gap: El Hana et al. (2024) propose an "emission-smart advertising" approach that weighs campaign performance against CO_2 emissions, and Istrate et al. (2024) measure the environmental cost of digital content consumption. Both, however, remain either conceptual or tied to a single campaign and offer no model that can be reused to compare channels. Sustainability research, for its part, has mostly examined infrastructure rather than application areas such as marketing. The gap therefore sits between digital marketing analytics and environmental sustainability.

As regulatory pressure and consumer awareness grow, firms need ways to weigh marketing effectiveness against environmental impact rather than treat them apart. Judging a channel on financial or engagement metrics alone is no longer enough; a fuller view has to capture the trade-off between marketing results and environmental responsibility.

MCDM methods suit this kind of problem because they handle several conflicting criteria at once and support a balanced assessment. Objective weighting methods such as CRITIC and MEREC set the importance of each criterion from the data, which lowers subjectivity. WASPAS, in turn, ranks alternatives by combining additive and multiplicative models.

This study therefore builds an integrated MCDM framework that evaluates digital marketing channels on both performance and sustainability. Alongside the usual performance metrics, it brings in carbon footprint and energy consumption as proxy sustainability indicators, with the aim of giving an engineering-oriented model that supports sustainable decisions in digital marketing.

To keep the analysis focused, and to go beyond simply presenting a computational model, the study is organised around three research questions:

RQ1. How can performance-oriented and sustainability-oriented criteria be combined in a single, objective and reproducible framework for evaluating digital marketing channels?

RQ2. How far does adding carbon footprint and energy consumption change the ranking of channels compared with a purely performance-based evaluation?

RQ3. How stable are the resulting rankings across different objective weighting methods and across changes in the WASPAS aggregation parameter?

The study contributes in three ways. It widens performance evaluation in digital marketing to include environmental criteria. It sets up an objective decision-support procedure based on established MCDM techniques. And it gives managers a clear view of the trade-off between performance and environmental impact across channels.

1.1. Literature Review

1.1.1. Digital marketing performance evaluation

Digital marketing sits at the centre of contemporary business strategy, largely because its channels are measurable. Effectiveness is usually read from indicators such as click-through rate (CTR), engagement, conversion and return on investment (ROI), which let firms see how users respond and adjust accordingly (Chaffey and Ellis-Chadwick, 2022; Martín-Cervantes et al., 2025).

The problem is that this literature stops at economic and behavioural outcomes and rarely looks at the wider effects of digital marketing. These metrics are useful for efficiency, but they say nothing about the energy and emissions tied to the underlying infrastructure, even as marketing leans more heavily on large-scale data processing. El Hana et al. (2024) make the same point: conventional media planning tends to put economic gain ahead of ecological cost, and few frameworks try to balance the two. That is the case for treating environmental criteria as proper decision variables rather than an afterthought.

1.1.2. Sustainability and the digital carbon footprint

Sustainability has become a central concern in both engineering and management, driven by environmental pressure and tighter regulation. For digital systems it usually comes down to energy efficiency and the emissions of computation. The digital carbon footprint is the total greenhouse-gas emissions from digital activity, including transmission, storage and processing (Caldeira et al., 2026).

Several studies report that data centres and cloud systems consume a large and growing share of energy (de Vries-Gao, 2025; Thangam et al., 2024), and that the expansion of the digital economy carries real environmental costs (Liu and Fang, 2025; Dzwigol et al., 2024). These findings undercut the assumption that digital technologies are inherently clean.

Transparency and efficiency in digital infrastructure have also been flagged as levers for better sustainability, from greener data-centre design to carbon-aware computing. Within online advertising itself, Pärssinen et al. (2018) produced one of the first systematic estimates of its energy and carbon footprint, and Istrate et al. (2024) showed that the environmental cost of digital content depends heavily on how it is delivered. What is still missing is the step from infrastructure to application: sustainability has rarely been applied to marketing systems themselves.

1.1.3. Theoretical framework: the natural-resource-based view

To give the study a firmer conceptual base, the framework is anchored in the Natural-Resource-Based View (NRBV) of the firm. Building on Barney's (1991) resource-based view, Hart (1995) argued that a firm's competitive position increasingly depends on how it manages its relationship with the natural environment, and identified capabilities such as pollution prevention and product stewardship that turn environmental performance into lasting advantage. Hart and Dowell (2011) later added clean technology to this account and pointed to digital systems and eco-innovation as carriers of environmental capability.

Seen through the NRBV, the carbon footprint and energy efficiency of a marketing channel count as strategic resources rather than external limits. A channel that delivers comparable marketing results at a lower environmental cost embodies a pollution-prevention capability in Hart's sense, and may give the firm an edge as regulation tightens and consumers pay closer attention. Framing the problem this way ties the engineering-oriented MCDM model to an established management theory and explains why building sustainability into channel selection is strategically meaningful, beyond its ethical appeal.

1.1.4. Multi-criteria decision-making (MCDM) in performance evaluation

MCDM methods have long been used for problems with several conflicting criteria, which makes them a natural fit where cost, efficiency and environmental impact have to be weighed together (Mardani et al., 2015).

Among these, objective weighting methods have drawn interest because they set criterion importance from the data instead of expert opinion. Diakoulaki et al. (1995) developed CRITIC, which weights criteria by their variability and their correlation with one another, giving more weight to those that carry more information. Keshavarz-Ghorabaee et al. (2021) introduced MEREC, which takes a different route and judges each criterion by how much overall performance changes when it is removed.

For ranking, Zavadskas et al. (2012) proposed WASPAS, which combines the weighted sum model (WSM) and the weighted product model (WPM) and so captures both additive and proportional effects. This pairing has held up well in recent sustainability work: CRITIC–WASPAS has been used for sustainable crop selection (Nandi et al., 2025), and MEREC-based models for sustainable energy and resource-management decisions (Dwi Putri Ariyanti and Fu'adi, 2025; Mondal et al., 2024). The track record supports applying the same combination to digital systems.

1.1.5. Research gap and contribution

Digital marketing performance and sustainability have each been studied closely, but rarely together in one framework. Marketing research stays with performance; sustainability research stays with infrastructure. The use of carbon footprint and energy consumption inside a marketing performance assessment has had little attention.

MCDM methods, too, are well established in engineering and decision-making but have seldom been turned on sustainability-oriented digital marketing. Set against the nearest existing work, this study differs in three concrete ways. First, it works at the channel level and yields a transferable ranking model, rather than assessing a single campaign as El Hana et al. (2024) do. Second, it places environmental indicators inside a formal, reproducible weighting-and-ranking procedure, rather than reporting footprints on their own (Pärssinen et al., 2018; Istrate et al., 2024). Third, as far as we are aware, it is the first to pair dual objective weighting (CRITIC and MEREC) with WASPAS and a Spearman-based stability test in this area.

To close this gap, the study builds an integrated MCDM framework that evaluates digital marketing channels on both performance and sustainability. By bringing carbon footprint and energy consumption into the evaluation through objective weighting, it connects marketing analytics to environmental sustainability.

2. Materials and Methods

The framework evaluates digital marketing channels on performance and sustainability together. It runs in three stages: building the decision matrix, weighting the criteria with two objective methods, and ranking the channels with a hybrid method.

2.1. Rationale for Method Selection

The choice of CRITIC, MEREC and WASPAS is deliberate. Subjective methods such as AHP or the Best-Worst Method rest on expert judgement, which would bring back the bias the study is trying to avoid, so they were set aside. Among objective methods, the Entropy method looks only at the spread of each criterion in isolation, whereas CRITIC also accounts for the correlation between criteria. That matters here, since several performance indicators (CTR, conversion, ROI) move together. MEREC was added as a second, logically independent method: it derives weights from the effect of removing each criterion, so running both lets the weighting stage be cross-checked. For ranking, WASPAS was preferred over distance-based methods such as TOPSIS or VIKOR because it blends WSM and WPM through one tunable parameter, which improves accuracy and also gives a natural handle for sensitivity analysis. The combined CRITIC/MEREC and WASPAS design has been validated in recent sustainability-oriented MCDM studies (Nandi et al., 2025; Dwi Putri Ariyanti and Fu'adi, 2025).

2.2. Decision Matrix Construction

The first step is a decision matrix of alternatives and criteria. Here the alternatives are digital marketing channels and the criteria cover both performance and sustainability. The matrix is written as $X = [x_{ij}]$ for $i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$, where x_{ij} is the value of alternative i on criterion j, m is the number of alternatives and n the number of criteria.

Criteria fall into two types: benefit criteria, to be maximised, and cost criteria, to be minimised. CTR and conversion are benefit criteria, while cost per click, carbon footprint and energy consumption are cost criteria.

Channels also differ in how much data they process and how much real-time optimisation they need, and these differences feed straight into energy use. The framework therefore captures the computational load of each channel alongside its marketing performance, which links marketing to system-level efficiency.

2.3. Normalization of the Decision Matrix

Because the criteria use different units, the matrix is normalized with linear normalization. For benefit criteria, $r_{ij} = x_{ij} / \max(x_j)$; for cost criteria, $r_{ij} = \min(x_j) / x_{ij}$, where r_{ij} is the normalized value of x_{ij} (equations 1 and 2).

$$r_{ij} = x_{ij} / \max(x_j) \quad \text{(benefit criteria)} \tag{1}$$

$$r_{ij} = \min(x_j) / x_{ij} \quad \text{(cost criteria)} \tag{2}$$

2.4. CRITIC Method for Objective Weighting

Diakoulaki et al. (1995) define CRITIC (Criteria Importance Through Intercriteria Correlation) so that the weight of each criterion depends on its variability and on its conflict with the others. The standard deviation σ_j of each criterion measures its contrast, and the correlation coefficients ρ_{jk} capture the conflict between criteria. The information content of each criterion is $C_j = \sigma_j \times \Sigma_k (1 - \rho_{jk})$, and the weights follow from normalizing C_j: $w_j = C_j / \Sigma C_j$ (equations 3 and 4).

$$C_j = \sigma_j \times \Sigma_k (1 - \rho_{jk}) \tag{3}$$

$$w_j = C_j / \Sigma C_j \tag{4}$$

2.5. MEREC Method for Objective Weighting

MEREC (Method based on the Removal Effects of Criteria) weights each criterion by its effect on overall performance when it is removed (Keshavarz-Ghorabaee et al., 2021). Overall scores S_i are computed from the normalized matrix with a logarithmic measure, and each criterion j is then dropped in turn to give $S_i(-j)$. The removal effect is $E_j = \Sigma_i |S_i - S_i(-j)|$, and the weights are $w_j = E_j / \Sigma E_j$ (equations 5 and 6).

$$S_i = \ln[1 + (1/m) \Sigma_j |\ln(r_{ij})|] \tag{5}$$

$$E_j = \Sigma_i |S_i - S_i(-j)|, \quad w_j = E_j / \Sigma E_j \tag{6}$$

2.6. WASPAS Method for Ranking Alternatives

WASPAS (Weighted Aggregated Sum Product Assessment) ranks alternatives by combining the strengths of the weighted sum and weighted product models (Zavadskas et al., 2012). The WSM score is $Q_i^1 = \Sigma_j w_j r_{ij}$ and the WPM score is $Q_i^2 = \Pi_j (r_{ij})^{w_j}$. The final score combines the two: $Q_i = \lambda Q_i^1 + (1 - \lambda) Q_i^2$. The parameter $\lambda \in [0, 1]$ sets the balance between the additive (WSM) and the multiplicative (WPM) parts of the WASPAS score itself; it does not weight the CRITIC and MEREC methods. Following common practice, λ is set to 0.5 as the baseline so the two parts contribute equally, and its effect on the rankings is examined in the sensitivity analysis (equations 7, 8 and 9).

$$Q_i^1 = \Sigma_j w_j r_{ij} \tag{7}$$

$$Q_i^2 = \Pi_j (r_{ij})^{w_j} \tag{8}$$

$$Q_i = \lambda Q_i^1 + (1 - \lambda) Q_i^2 \tag{9}$$

2.7. Integrated Evaluation Framework

CRITIC and MEREC are applied separately to obtain two sets of weights, and WASPAS then ranks the channels under each set. Running two weighting methods rather than one lets the stability of the weights be checked, and the framework evaluates marketing performance and sustainability at the same time, which makes it a usable decision-support tool for selecting efficient and environmentally responsible channels.

2.8. Alternatives and Criteria Selection

The alternatives are five widely used channels, the platforms firms rely on most in digital marketing: A1 Social Media Marketing, A2 Paid Search Advertising, A3 Display Advertising, A4 Email Marketing and A5 Influencer Marketing.

The criteria, drawn from the digital marketing and sustainability literature, split into a performance group and a sustainability group.

2.9. Performance Criteria

Performance criteria reflect how effective a channel is in terms of user interaction and financial return: C1 Click-Through Rate (CTR), the share of users who click an advertisement (benefit); C2 Engagement Rate, the level of user interaction (benefit); C3 Conversion Rate, how well users become customers (benefit); C4 Cost per Click (CPC), the cost per click (cost); and C5 Return on Investment (ROI), profitability (benefit).

2.10. Sustainability Criteria

Two sustainability criteria bring the environment into the evaluation: C6 Carbon Footprint Score, the estimated carbon emissions of each channel (cost), and C7 Energy Consumption Proxy, the relative energy needed to run each channel (cost).

Because emissions from marketing channels cannot be measured directly, C6 and C7 use proxy values taken from work on digital infrastructure, data-processing intensity and platform-level resource use (de Vries-Gao, 2025; Caldeira et al., 2026). Channels that depend on real-time bidding, large-scale data processing and constant algorithmic optimisation are assumed to carry a higher carbon impact. This proxy approach follows earlier digital-sustainability studies where direct measurement was not feasible.

The carbon footprint (C6) is estimated from a proxy model based on data transmission and computational intensity. Emissions are approximated as (equation 10):

$$C6 = \text{Data Transfer (MB)} \times \text{Energy Intensity (kWh/MB)} \times \text{Carbon Intensity } (gCO_2e/kWh) \tag{10}$$

where data transfer is the average volume per user interaction, energy intensity is the energy needed to process and transmit that data, and carbon intensity is the emission factor of the electricity used. Energy consumption (C7) is treated as a function of computational load and system-level processing. This keeps the environmental estimates inside the same evaluation as the performance metrics.

2.11. Data Construction

The decision matrix combines benchmark values from the literature with computational energy coefficients. To keep the dataset open to scrutiny, the source of each value is stated. Performance values (C1–C5) follow published digital-marketing benchmark ranges from industry and academic sources (Chaffey and Ellis-Chadwick, 2022; Martín-Cervantes et al., 2025): email is given the strongest CTR, engagement, conversion and ROI together with the lowest CPC, in line with widely reported benchmarks, while display advertising takes the weakest performance values. The sustainability values (C6–C7) are set in proportion to each channel's data volume and its reliance on real-time bidding and algorithmic processing, following the evidence that programmatic and display channels are the most energy-intensive and email among the least (Pärssinen et al., 2018; Centre for Social Innovation, 2025; El Hana et al., 2024). Display and paid search therefore receive the worst carbon and energy scores, and email the best. The matrix is not arbitrary but a literature-calibrated, ordinally consistent picture of known channel characteristics. Benchmark-based data of this kind is common in MCDM studies whose aim is to demonstrate a method rather than to report a field measurement.

All values are normalized to a comparable range. The dataset reflects realistic differences in both performance and environmental impact across channels and so captures the economic and environmental trade-off in a controlled setting.

2.12. Decision Matrix and Criteria Classification

The decision matrix is given in Table 1. The benefit criteria are C1, C2, C3 and C5; the cost criteria are C4, C6 and C7. This split governs how normalization and weighting are applied. With the dataset in place, the next section applies the framework and reports the ranking.

Applying the linear normalization in equations (1) and (2) to the raw data brings every criterion onto a common 0–1 scale. Table 2 reports the normalized decision matrix that underlies all later calculations.

Table 1. Decision matrix of digital marketing channels

Alternatives	CTR (C1)	Eng. (C2)	Conv. (C3)	CPC (C4)	ROI (C5)	Carbon (C6)	Energy (C7)
A1 Social Media	0.045	0.120	0.035	0.80	2.50	0.65	0.70
A2 Paid Search	0.060	0.090	0.045	1.20	3.20	0.85	0.90
A3 Display Ads	0.030	0.050	0.020	0.60	1.80	0.75	0.80
A4 Email Marketing	0.070	0.150	0.055	0.40	3.80	0.40	0.45
A5 Influencer Marketing	0.050	0.130	0.040	1.00	3.00	0.70	0.75

Table 2. Normalized decision matrix

Alternatives	C1	C2	C3	C4	C5	C6	C7
A1 Social Media	0.643	0.800	0.636	0.500	0.658	0.615	0.643
A2 Paid Search	0.857	0.600	0.818	0.333	0.842	0.471	0.500
A3 Display Ads	0.429	0.333	0.364	0.667	0.474	0.533	0.562
A4 Email Marketing	1.000	1.000	1.000	1.000	1.000	1.000	1.000
A5 Influencer Marketing	0.714	0.867	0.727	0.400	0.789	0.571	0.600

3. Results

3.1. Criteria Weights

The weights come from two objective methods, CRITIC and MEREC, each judging criterion importance from data variability and from the removal effect on overall performance. Both sets, recomputed directly from the normalized decision matrix, appear in Table 3.

Table 3. Objective criteria weights obtained from CRITIC and MEREC

Criteria	CRITIC Weights	MEREC Weights
C1 (CTR)	0.124	0.151
C2 (Engagement)	0.166	0.220
C3 (Conversion)	0.128	0.191
C4 (CPC)	0.267	0.154
C5 (ROI)	0.109	0.132
C6 (Carbon)	0.105	0.078
C7 (Energy)	0.100	0.073

Under CRITIC, cost per click (C4, 0.267) and engagement (C2, 0.166) carry the most information, reflecting their high variability and low correlation with the rest. Under MEREC, engagement (C2, 0.220) and conversion (C3, 0.191) come out on top. The two sustainability criteria together hold about 0.20 of the weight under both methods, so environmental factors have a real influence on the result rather than a marginal one.

3.2. Ranking of Alternatives Using WASPAS

WASPAS then ranks the channels under each set of weights, with λ = 0.5 so the additive and multiplicative parts of the score count equally. The results appear in Table 4.

Table 4. WASPAS scores and rankings under CRITIC and MEREC weights (λ = 0.5)

Alternatives	WASPAS (CRITIC)	Rank	WASPAS (MEREC)	Rank
A1 Social Media	0.625	3	0.651	3
A2 Paid Search	0.573	4	0.638	4
A3 Display Ads	0.490	5	0.449	5
A4 Email Marketing	1.000	1	1.000	1
A5 Influencer Marketing	0.627	2	0.682	2

Both weighting methods agree. Email Marketing (A4) ranks first, followed by Influencer Marketing (A5) and Social Media (A1). Paid Search (A2) is fourth and Display Advertising (A3) last in both cases. The two rankings match exactly, a first sign that the framework is stable; Section 3.3 tests this formally.

The two WASPAS components behave consistently. Table 5 lists the additive (WSM) and multiplicative (WPM) scores together with the combined score Qi under CRITIC weights. The close agreement between WSM and WPM is why the final ranking does not depend on the weight placed on either component.

Table 5. WASPAS component scores (WSM, WPM) and combined score under CRITIC weights

Alternatives	WSM	WPM	Qi
A1 Social Media	0.628	0.622	0.625
A2 Paid Search	0.591	0.554	0.573
A3 Display Ads	0.497	0.482	0.490
A4 Email Marketing	1.000	1.000	1.000
A5 Influencer Marketing	0.638	0.615	0.627

3.3. Statistical Validation of Ranking Consistency

To check the agreement between the two rankings, the Spearman rank correlation coefficient (rs) was computed between the CRITIC-based and MEREC-based orders. Since the two are identical for all five channels, the coefficient takes its maximum value, rs = 1.000 (P<0.001). A value of 1.000 means the two orders agree perfectly, so the outcome does not depend on whether CRITIC or MEREC is used. Because the analysis rests on objective, fully reproducible computation rather than survey data, no further inferential testing was needed.

3.4. Criterion-Group Contribution Analysis

To see whether Email's lead comes mainly from its economics or its sustainability, the weighted-sum score was split into the two criterion groups (CRITIC weights). For Email Marketing, performance criteria (C1–C5) account for about 79.5% of the score and sustainability criteria (C6–C7) for the remaining 20.5%. The other channels show a similar split, with performance contributions between roughly 77% and 83%. So Email's first place rests mainly on strong economics, in particular its high ROI and low cost per click, and is reinforced by its low carbon and energy footprint. Sustainability does not decide the ranking on its own, but it is decisive at the margin: it widens the gap between Email and the more computation-heavy channels and is enough to penalise Paid Search and Display Advertising. Table 6 reports the decomposition.

Table 6. Decomposition of the weighted-sum score into performance and sustainability contributions (CRITIC weights)

Alternatives	Performance share	Sustainability share	Total
A1 Social Media	79.5%	20.5%	0.629
A2 Paid Search	83.2%	16.8%	0.591
A3 Display Ads	77.4%	22.6%	0.498
A4 Email Marketing	79.5%	20.5%	1.000
A5 Influencer Marketing	81.2%	18.8%	0.639

3.5. Comparative and Sensitivity Analysis

The close agreement between the CRITIC and MEREC results points to a stable framework.

Adding the sustainability criteria changes the ranking by penalising channels with a heavier environmental load: those with more computation and data processing slip down once carbon and energy are counted. A purely performance-based evaluation would miss this and could lead to weaker decisions.

To test sensitivity to the WASPAS parameter, λ was varied from 0.1 to 0.9. As Figure 1 shows, Email Marketing (A4) stays first and Display Advertising (A3) last across the whole range, and Paid Search (A2) stays fourth. The only change is a swap between Social Media (A1) and Influencer Marketing (A5) for second and third place at low λ values (λ ≤ 0.3), where the multiplicative part dominates. The ranking is thus highly, though not perfectly, stable: the top and bottom positions do not move, and only the closely scored middle channels interchange under extreme settings. The main conclusions do not depend on the choice of λ = 0.5.

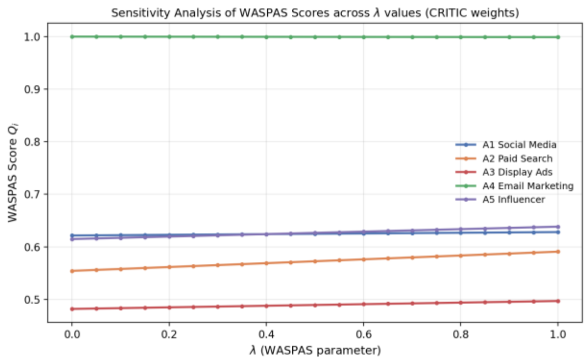

Figure 1. Sensitivity analysis of WASPAS scores across different λ values (CRITIC weights).

Table 7 gives the full ranking at each value of λ from 0.1 to 0.9. It confirms in numbers what Figure 1 shows: the first and last positions never move, and only A1 and A5 trade second and third place at λ ≤ 0.3.

Table 7. Rankings of alternatives across λ values (CRITIC weights)

λ	A1	A2	A3	A4	A5
0.1	2	4	5	1	3
0.2	2	4	5	1	3
0.3	2	4	5	1	3
0.4	3	4	5	1	2
0.5	3	4	5	1	2
0.6	3	4	5	1	2
0.7	3	4	5	1	2
0.8	3	4	5	1	2
0.9	3	4	5	1	2

3.6. Key Findings

Taken together, the sustainability criteria clearly shape the outcome. Email marketing comes out as the most efficient channel because it pairs strong performance with a low footprint; performance-led channels such as paid search stay competitive but pay for their higher environmental cost; and including carbon footprint gives a more realistic assessment than performance alone. Bringing sustainability into the evaluation thus leads to different strategic conclusions than a performance-only approach would.

4. Discussion

The results say something useful about how digital marketing channels look once environmental cost is part of the picture. Counting carbon footprint and energy consumption gives a fuller, more balanced assessment than performance metrics alone, and it reframes channel selection as much as an engineering problem as a marketing one. This fits the NRBV logic set out in Section 1.1.3: a channel that meets its marketing goals at a lower environmental cost holds a pollution-prevention capability and can turn that efficiency into advantage (Hart, 1995; Hart and Dowell, 2011).

In line with earlier work on the footprint of digital infrastructure (de Vries-Gao, 2025; Caldeira et al., 2026), the channels differ in both efficiency and environmental impact, and the ones that lean on data processing, real-time bidding and algorithmic optimisation carry the higher carbon and energy load. This supports the broader point that digital systems, intangible as they are, have real environmental consequences.

Email Marketing comes out as the most efficient option, partly because it depends less on heavy computation and moves less data than the other channels. As the decomposition in Section 3.4 shows, though, this lead rests mostly on economics (about 80% of the score) and is reinforced rather than caused by its sustainability advantage. Display Advertising sits at the bottom, where weak economic indicators meet a high environmental cost; much of that cost comes from the constant real-time data exchange and algorithmic decisions in programmatic bidding. Industry evidence backs this up, placing programmatic and real-time-bidding channels among the most carbon-intensive in the ecosystem (Pärssinen et al., 2018; El Hana et al., 2024; Centre for Social Innovation, 2025).

The comparison with the nearest prior work sharpens the contribution. El Hana et al. (2024) balance performance and emissions for a single campaign through a qualitative Delphi procedure; the present framework works at the channel level and produces a reproducible quantitative ranking. The two are complementary. Both conclude that economic and ecological goals have to be optimised together, but this model offers a tool that can be reapplied whenever channel-level benchmark data are available.

Running CRITIC and MEREC together also helps. The two produced the same ranking, which suggests the framework is stable and reliable, in line with earlier findings that objective weighting lowers subjectivity in MCDM (Keshavarz-Ghorabaee et al., 2021).

On the theory side, the study links digital marketing analytics with sustainability research, two areas usually kept apart, and shows that environmental considerations can be folded into marketing evaluation. That pushes marketing research beyond its usual economic and behavioural metrics and places digital systems within the wider frame of sustainable engineering.

On the practical side, managers can use the framework to pick channels that perform well while keeping environmental impact down. This matters as regulation tightens and consumers grow more aware of sustainability, and firms that move this way may also gain on brand reputation.

These implications become concrete with a simple example. Take a firm that currently splits its budget evenly between display advertising and email. Under the present ranking, moving part of that budget from display, which sits last and carries the heaviest footprint, toward email, which leads on both performance and sustainability, would lift marketing returns and cut carbon and energy use together. The shift also pays off in the market. Nguyen et al. (2025) find that a green marketing mix raises customer commitment and willingness to pay a premium, and Tan et al. (2025) show that a strategic green marketing orientation feeds business performance through perceived competitive advantage. Read with the NRBV, then, a channel mix that lowers environmental cost is both cheaper to operate and a source of advantage in its own right.

The study has limits. It rests on benchmark-based rather than field data, which keeps the method clear but restricts how far the results generalise. The sustainability criteria use proxies because direct emissions data for marketing channels are not available. Future work could bring in real datasets and sharper measurement of the digital carbon footprint.

5. Conclusion

This study set out an integrated MCDM framework for evaluating digital marketing channels on performance and environmental sustainability at once. Pairing CRITIC and MEREC weighting with WASPAS ranking gave a systematic and reproducible model.

The results show that adding carbon footprint and energy consumption changes the evaluation in a real way. Answering the research questions directly: performance and sustainability can be combined in a single objective and reproducible model (RQ1); including environmental criteria reshapes the standing of channels by penalising the computation-heavy ones (RQ2); and the rankings stay stable across weighting methods (r_s = 1.000) and across the WASPAS parameter (RQ3). A performance-only assessment risks biased or incomplete decisions once environmental cost is ignored.

One result stands out: a low-energy channel such as email can finish first overall once sustainability is in the mix, which means environmentally efficient channels can also be competitive when judged on the full set of criteria. Sustainability is better treated as part of strategic marketing decisions than as a secondary concern.

Methodologically, using two objective weighting methods strengthens the result, and the agreement between CRITIC and MEREC suggests the framework is stable enough for harder problems. The WASPAS step provides a balanced way to aggregate that reflects both linear and proportional effects.

On the theory side, the study connects digital marketing analytics with sustainability evaluation and grounds the link in the Natural-Resource-Based View. On the practical side, it gives managers a decision-support tool for designing more sustainable digital marketing strategies.

Its limits should be acknowledged. The analysis rests on benchmark-driven data, which may limit how far the findings generalise, and the sustainability indicators are proxies because direct emissions data are not available. Future work could use real-world datasets and sharper footprint estimation. On balance, bringing sustainability into digital marketing evaluation is both workable and necessary for decisions meant to last.

Author Contributions

The percentages of the author's contributions are presented below. The author reviewed and approved the final version of the manuscript.

	S.O.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because there was no study on animals or humans.

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