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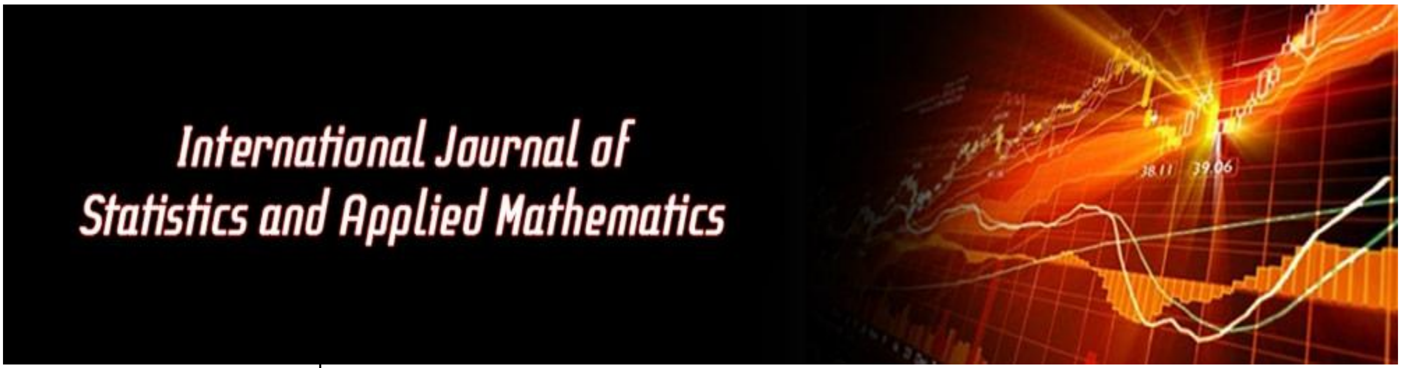

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A hybrid intuitionistic fuzzy TOPSIS-FCM framework for evaluating digital marketing effectiveness

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Abstract
Digital marketing environments are characterized by uncertainty, behavioral variability, and nonlinear interactions among consumer touchpoints, making traditional evaluation approaches insufficient. This study proposes a hybrid decision-making framework integrating Intuitionistic Fuzzy TOPSIS (IF-TOPSIS) and Fuzzy Cognitive Mapping (FCM) to measure digital marketing effectiveness under uncertain conditions. Six criteria-mobile engagement, parasocial relationship potential, influencer credibility, organic traffic, cross-device consistency, and digital readiness-were identified from the literature. Four digital marketing strategies were evaluated using a synthetic, expert-driven linguistic decision matrix converted into intuitionistic fuzzy numbers and weighted through entropy. IF-TOPSIS results show that mobile-interactive strategies outperform cross-device, desktop-centric, and non-personalized campaigns. The FCM model reveals that mobile usage, parasocial engagement, and credibility exert strong causal influence on overall effectiveness, validating the IF-TOPSIS ranking. Results highlight that digital marketing performance is shaped by both evaluative uncertainty and dynamic causal processes, underscoring the need for hybrid analytical methods. The study provides theoretical insights into fuzzy modeling in digital contexts and practical guidance on prioritizing strategies that leverage mobile-based engagement and relational cues.

Keywords: Intuitionistic fuzzy TOPSIS, fuzzy cognitive maps (FCM), digital marketing effectiveness, multi-criteria decision making (MCDM), entropy weighting

1. Introduction
Digital marketing has become one of the core strategic tools for contemporary organizations attempting to influence, attract, and retain consumers across multiple digital touchpoints. As digital ecosystems grow increasingly complex-integrating mobile browsing, social media platforms, AI-driven feeds, recommendation systems, influencer content, and multi-device usage, consumer behavior has become more ambiguous, imprecise, and non-linear. Traditional analytical frameworks, which assume stable, crisp, and deterministic behavioral rules, often fail to capture the uncertainty embedded in online engagement patterns (Zadeh, 1965; Atanassov, 1986) [30, 3].
Recent studies highlight that digital interactions frequently exhibit fuzzy characteristics, where user intent, engagement intensity, and channel preference cannot be classified into fixed categories. For instance, research on influencer marketing demonstrates that constructs such as attractiveness, prestige, parasocial relationships, and authenticity involve subjective perception and ambiguous emotional responses that vary across individuals (Aw *et al.*, 2023) [5]. Similarly, large-scale digital adoption studies show persistent disparities and asymmetries in how different population groups utilize digital technologies, with fuzzy-set analyses revealing varying degrees of digital readiness and technological convergence (Kolupaieva & Tiesheva, 2023) [15].
The growing reliance on mobile-first behavior has further increased uncertainty within digital environments. Mobile interactions are frequent, short, and context-sensitive, often generating fluctuating engagement metrics, while desktop interactions tend to be deeper but less frequent (Sakas & Giannakopoulos, 2021) [23].

These multidimensional behaviors create data distributions that are irregular, ambiguous, and often contradictory-making them particularly suitable for fuzzy modeling techniques.

Fuzzy-based decision-making frameworks, especially those integrating fuzzy sets, intuitionistic fuzzy logic, and fuzzy graphs, have proven to be powerful for modeling uncertain digital scenarios (Shoaib *et al*., 2021) [25]. Moreover, multi-criteria decision-making (MCDM) models such as fuzzy AHP, fuzzy TOPSIS, and intuitionistic fuzzy TOPSIS have been widely applied in digital-related decision domains-ranging from e-commerce platform evaluation to technology selection-due to their ability to handle incomplete and hesitant expert judgments (Zhang *et al*., 2017) [31].

However, despite the rapid expansion of digital marketing scholarship, there is limited research integrating fuzzy logic and MCDM methods directly into the evaluation of digital marketing effectiveness. Existing work often focuses on isolated aspects: influencer behavior (Aw *et al*., 2023) [5], device-based digital behavior (Sakas & Giannakopoulos, 2021) [23], or digital gaps and adoption discrepancies (Kolupaieva & Tiesheva, 2023) [15]. Yet modern digital marketing effectiveness emerges not from individual factors but from interactions across multiple uncertain touchpoints, including device environment, social engagement attributes, technological readiness, and content-driven perception.

To address this gap, the present study proposes a hybrid fuzzy multi-criteria decision-making framework that integrates:

- Intuitionistic Fuzzy TOPSIS for evaluating digital marketing strategies under uncertain, hesitant linguistic assessments.
- Fuzzy Cognitive Mapping (FCM) for modeling causal, dynamic relationships among digital variables such as mobile usage, influencer engagement attributes, web-traffic metrics, and perceived digital value.

This integration captures both *the evaluative dimension* (ranking strategies) and *the causal dimension* (understanding how variables interact), offering a comprehensive tool for analyzing digital marketing performance in uncertain environments.

The remainder of this paper is organized as follows: Section 2 provides an expanded literature review on fuzzy logic and digital marketing; Section 3 presents the hybrid methodology; Section 4 reports empirical findings; Section 5 discusses theoretical and managerial implications; and Section 6 concludes with contributions and future research directions.

2. Literature Review

2.1 Fuzzy Logic and Fuzzy Multi-Criteria Decision-Making

The foundations of fuzzy modeling in decision-making trace back to the introduction of fuzzy sets by Zadeh (1965) [30] further expanded through later fuzzy decision frameworks (Garg & Arora, 2021) [10], who proposed membership functions to capture partial belonging under vagueness, and to Atanassov's extension to intuitionistic fuzzy sets, where truth, falsity, and hesitation are modeled simultaneously (Atanassov, 1986) [3]. These concepts laid the groundwork for fuzzy multi-criteria decision-making (MCDM), which has since been extensively applied in complex environments where information is incomplete, subjective, or conflicting. Recent surveys emphasize that fuzzy MCDM techniques are particularly suitable for service, marketing, and tourism contexts, where decision variables are qualitative and linguistic rather than purely numerical (Liao *et al*., 2023) [18].

Methods such as fuzzy AHP, fuzzy TOPSIS, intuitionistic fuzzy TOPSIS, VIKOR, and hybrid combinations have gained prominence because they can handle ambiguous expert judgments and transform them into structured, comparable evaluations. Zhang *et al*. (2017) [31], for example, used entropy-weighted intuitionistic fuzzy TOPSIS for logistics center location selection, showing that the combination of information-theoretic weights and intuitionistic fuzzy distances yields robust rankings in uncertain environments (Garg *et al*., 2022) [11]. These developments collectively establish fuzzy MCDM as a mature and flexible methodological family that is well aligned with the nature of uncertainty in digital marketing contexts.

2.2 Fuzzy MCDM Applications in E-Commerce and Digital Contexts

A substantial body of work has applied fuzzy MCDM to e-commerce and online strategy evaluation. Chiu *et al*. (2004) [8] proposed one of the earlier fuzzy MCDM models for evaluating and selecting e-commerce strategies, arguing that linguistic assessments of strategic criteria-such as customer service, security, and usability-are better represented through fuzzy scales than crisp scores. Aydin and colleagues developed a fuzzy AHP-based methodology to evaluate e-commerce website quality, incorporating both positive and negative fuzzy numbers to account for advantages and drawbacks in site features (Aydin & colleagues, 2010) [4]. Their work illustrates that website quality evaluation is inherently multi-criteria and fuzzy, depending on subjective perceptions of usability, efficiency, and service quality rather than deterministic metrics alone.

In the mobile commerce domain, Kabir *et al*. (2011) [13] used fuzzy AHP to identify and prioritize customer-oriented success factors in mobile commerce, emphasizing the impact of perceived convenience, service reliability, and interface quality on adoption and satisfaction (Pradhan *et al*., 2020) [22]. Their findings highlight that mobile environments intensify uncertainty because usage is context-dependent and often fragmented across time and space. More recent studies extend these ideas to digital marketing tool selection. Şengül and co-authors employed a combined fuzzy AHP-fuzzy TOPSIS model to select digital marketing tools, revealing that remarketing and social media advertising rank highly when evaluated under fuzzy multi-criteria conditions that include effectiveness, cost, and engagement potential.

In parallel, fuzzy MCDM has been applied to evaluate digital and e-commerce technologies. Trung *et al*. (2022) [28] and Singh & Kaur (2021) [26] proposed a spherical fuzzy MCDM model to support decision makers in evaluating digital marketing technologies, showing that extended fuzzy representations can better reflect hesitation and ambiguity in expert opinions when criteria involve both technical and strategic dimensions. Kumar *et al*., 2024 [16] recently used a fuzzy TOPSIS approach to analyze the role of digital technologies in e-commerce platforms, finding that technologies such as cloud marketing and big data analytics rank highest when both qualitative benefits and quantitative performance are taken into account. Together, these studies demonstrate that fuzzy MCDM provides a powerful toolbox for evaluating e-commerce strategies, website quality, mobile commerce success, and digital marketing technology options under uncertainty.

2.3 Consumer Behavior, Social Media, and Fuzzy Perception:

Beyond classical and intuitionistic fuzzy sets, more advanced fuzzy representations have been proposed to capture the multi-dimensional uncertainty present in digital ecosystems. Picture fuzzy graphs, for instance, extend fuzzy and intuitionistic fuzzy graphs by incorporating positive, neutral, and negative membership degrees simultaneously. Shoaib *et al*. (2021) [25] show that picture fuzzy graphs can effectively represent complex networked structures, such as social or digital networks, where vertices and edges often exhibit mixed states rather than strictly positive or negative relationships. This multi-valued structure is particularly relevant for social media and digital marketing environments, where user reactions may be supportive, indifferent, or resistant, and where neutrality itself carries analytical significance.

Fuzzy cognitive mapping has also gained traction as a means of modeling causal structures in digital contexts. Sakas and Giannakopoulos (2021) [23] applied fuzzy cognitive maps combined with agent-based modeling to study how desktop and mobile device usage patterns influence airlines' digital brand name metrics over time. Their model incorporated web analytics indicators such as organic, direct, and referral traffic, along with device-based visits, unique visitors, and pages per visit, demonstrating that mobile usage had a slightly stronger impact on several brand-related indicators while desktop traffic remained critical for referral-based visibility. The study, supported by similar FCM-based digital modeling research (Barroso *et al*., 2021) [6], underscores that digital brand equity arises from non-linear, uncertain interactions among multiple variables, making FCM a suitable framework for capturing dynamic relationships in digital marketing.

In a broader digital transformation context, Kolupaieva and Tiesheva (2023) [15] used fuzzy sets to measure asymmetry and convergence in the development of digital technologies across EU countries, evaluating access to transactional (e-commerce), informational (cloud computing), and operational (AI) technologies. Their findings reveal persistent digital gaps and differentiated convergence patterns, suggesting that digital readiness is itself a fuzzy construct that shapes the effectiveness of digital strategies, including marketing. These advanced fuzzy models collectively illustrate that modern digital systems require analytical approaches capable of capturing multiple dimensions of uncertainty-membership, non-membership, hesitation, neutrality, and evolving causal influence.

2.4 Digital Marketing Performance Measurement and Metrics

Parallel to the methodological advances in fuzzy modeling, there has been sustained interest in defining and measuring digital marketing performance. Early work using a balanced scorecard approach adapted classical performance perspectives to digital media, emphasizing customer, internal, innovation, and financial dimensions as a framework for assessing digital campaigns and channels (various authors, e.g., balanced-scorecard-based digital performance frameworks; Samanlioglu *et al*., 2023) [24]. More recent literature has focused explicitly on digital marketing metrics and ROI analysis, synthesizing how businesses can track and optimize performance using indicators such as click-through rates, conversion rates, cost per acquisition, and engagement metrics (Kumar & co-authors, 2023; representative ROI and metrics reviews; Dhar & Stein, 2017) [17, 9]. These studies collectively point out that, although digital environments offer a wealth of measurable data, performance measurement practices remain fragmented and are often not aligned with strategic objectives (Wang & Yu, 2017) [29].

A related line of inquiry examines key performance indicators (KPIs) in digital transformation. Mahboub (2023) [19], for example, conducted a systematic literature review of digital transformation KPIs and found that managers often underutilize structured KPI frameworks, leading to gaps between digital initiatives and observable performance outcomes. Similar concerns arise in the specific domain of social media marketing, where Ascani *et al*. (2025) [2] identify significant challenges in measuring social media marketing performance due to inconsistencies in platform metrics, attribution complexity, and the difficulty of translating engagement into business outcomes. Complementing these perspectives, Rajesh Kumar (2022) highlights the importance of marketing metrics as quantifiable indicators that connect marketing actions with performance, framing them as critical tools for evidence-based decision-making in the digital era.

Data analytics-oriented studies further emphasize the need to integrate web analytics, social media data, and customer information into cohesive evaluation frameworks (Zheng *et al*., 2020) [32]. Al Adwana (2023) [1] discusses how digital data analytics can be used to assess website performance, track social media activity, and analyze email marketing effectiveness, noting that many organizations still struggle to convert raw digital data into actionable strategic insight (Ha *et al*., 2015) [12]. Collectively, this body of work converges on the view that digital marketing performance is multi-dimensional, dependent on both behavioral engagement signals and strategic alignment, and that existing deterministic approaches are often insufficient to capture the underlying uncertainty and complexity.

2.5 Digital Consumer Behavior and Fuzzy Perception

Digital consumer behavior literature reinforces the argument that digital marketing dynamics are fundamentally fuzzy. Aw *et al*. (2023) [5] showed that parasocial relationships with social media influencers, driven by content attributes such as prestige and expertise and interaction strategies such as interactivity and self-disclosure, play a central role in shaping purchase intentions. Their use of PLS-SEM combined with fuzzy-set Qualitative Comparative Analysis (fsQCA) revealed that different configurations of engagement attributes can lead to similar outcomes, illustrating the principle of equifinality in digital persuasion. Rather than yielding a single linear cause-effect relationship, the results indicate that digital endorsement success depends on combinations of fuzzy antecedent conditions, further justifying the use of fuzzy logic in modeling these phenomena.

These insights, together with the digital gap evidence reported by Kolupaieva and Tiesheva (2023) [15] and the device-based behavioral patterns identified by Sakas and Giannakopoulos (2021) [23], suggest that digital marketing effectiveness is shaped by an interplay of perceptual, technological, and behavioral uncertainties. Parasocial bonds, perceived influencer credibility, device usage habits, and differential access to advanced digital technologies all interact in ways that defy crisp categorization. Fuzzy MCDM and fuzzy cognitive models therefore provide a conceptually consistent means of integrating these diverse dimensions into a unified evaluative framework.

2.6 Identified Research Gap

Although there is substantial literature applying fuzzy MCDM to e-commerce website evaluation, technology selection, mobile commerce success factors, and even digital marketing tools, most existing works treat these applications in a single-layer manner, focusing either on tool or platform selection (Trung *et al*., 2022; Kumar *et al*., 2024) [28, 16] or on isolated performance measurement frameworks. At the same time, studies on influencer marketing, digital gaps, and device-specific engagement provide rich insights into behavioral and contextual uncertainty (Aw *et al*., 2023; Kolupaieva & Tiesheva, 2023; Sakas & Giannakopoulos, 2021) [5, 15, 23], but they do not integrate these elements into a unified fuzzy decision-making model.

Consequently, there remains a clear gap for a hybrid model that simultaneously:

1. Evaluates alternative digital marketing strategies using fuzzy multi-criteria evaluation under hesitant and linguistic information.
2. Models the causal interdependencies among digital touchpoints such as device usage, engagement attributes, traffic sources, and perceived digital value.

The present study addresses this gap by proposing and implementing a hybrid framework that integrates intuitionistic fuzzy TOPSIS with fuzzy cognitive mapping to evaluate digital marketing effectiveness across consumer touchpoints under uncertainty.

3. Methodology

The methodological design of this study integrates two complementary fuzzy-based analytical approaches, intuitionistic fuzzy TOPSIS (IF-TOPSIS) and fuzzy cognitive mapping (FCM), to evaluate digital marketing effectiveness across uncertain consumer touchpoints (Belouaar *et al*., 2018) [7]. The hybridization of these methods is grounded in the premise that digital marketing performance arises from both evaluative uncertainty and causal complexity, requiring a methodological architecture capable of capturing subjective judgments, nonlinear interactions, and hesitation in expert assessments (Barroso *et al*., 2021) [6].

3.1 Identification of Evaluation Criteria

The first stage of the methodology involves identifying the criteria that most accurately capture the multidimensional nature of digital marketing effectiveness. Because digital marketing operates within an environment shaped by uncertainty, perceptual ambiguity, and rapidly changing user behaviors, the criteria must reflect both the behavioral and technological dimensions documented in recent literature. Studies on digital consumer engagement show that variables such as content attractiveness, perceived expertise, prestige, interactivity, and self-disclosure significantly shape consumer attitudes through parasocial relationships, indicating that perceptual and psychological constructs are crucial in digital influence dynamics (Aw *et al*., 2023) [5]. Parallel research examining device-based asymmetry reveals that mobile and desktop users behave in fundamentally different ways, with mobile interactions characterized by frequent but brief sessions and desktop interactions associated with deeper, more deliberate engagement. These behavioral distinctions directly influence organic, direct, and referral traffic, which have been identified as core indicators of digital brand performance (Sakas & Giannakopoulos, 2021) [23].

In addition to these behavioral variables, structural and contextual factors also play a critical role. Digital readiness, access to advanced technologies, and the presence of digital capability gaps shape the extent to which individuals and organizations can effectively participate in online environments, as demonstrated in digital convergence studies across various sectors (Kolupaieva & Tiesheva, 2023) [15]. At the same time, fuzzy MCDM applications in e-commerce and mobile commerce consistently highlight criteria such as usability, customer experience, system responsiveness, content quality, perceived credibility, and technological familiarity as central components in evaluating online strategies (Chiu *et al*., 2004; Aydin *et al*., 2010; Kabir *et al*., 2011) [8, 4, 13]. These studies reinforce the understanding that digital performance cannot be captured through a single dimension but emerges from an intersection of experiential, behavioral, and technological variables.

Given the inherently fuzzy nature of these constructs, where evaluations are expressed linguistically (e.g., “high engagement,” “moderate trust,” “low mobile depth”) rather than numerically, fuzzy logic offers an appropriate means of translating subjective judgments into analyzable forms. Therefore, the criteria defined for the present study incorporate elements from psychological engagement literature, device-based behavioral analytics, digital readiness assessments, and established fuzzy MCDM frameworks. This integration ensures that the evaluation of digital marketing strategies accounts for the uncertainty, hesitation, and qualitative variability that characterize modern digital ecosystems, providing a robust foundation for the subsequent intuitionistic fuzzy modeling process.

3.2 Intuitionistic Fuzzy Representation of Linguistic Judgments

After establishing the relevant evaluation criteria, the next methodological step involves translating expert assessments into a form that can rigorously represent uncertainty, hesitation, and subjective perception. In digital marketing environments, expert evaluations rarely take the form of precise numerical values; instead, they are typically expressed using qualitative linguistic terms such as *high engagement*, *moderate influence*, or *low mobile depth*. These expressions inherently contain ambiguity and hesitation, as experts may be unsure about the precise boundaries of their judgments or may perceive overlapping degrees of truth and falsity within the same evaluation. Classical fuzzy sets, initially introduced by Zadeh (1965) [30], offer a partial solution by representing gradations of membership; however, digital marketing phenomena often require a more refined model that can capture not only degrees of truth but also degrees of falsity and the uncertainty that lies in between. Atanassov’s (1986) [3] intuitionistic fuzzy set (IFS) framework provides this capability by expressing each evaluation through three components: membership (truth), non-membership (falsity), and hesitation (the degree of uncertainty or incompleteness in the judgment).

In digital marketing applications, this tripartite structure is particularly valuable. Many of the criteria involved, such as perceived influencer credibility, emotional resonance, parasocial intimacy, and platform-specific engagement patterns, are inherently fuzzy in the cognitive and behavioral sense. For instance, consumers often perceive influencer traits simultaneously as attractive and relatable but may hesitate to fully endorse their expertise or authenticity, reflecting the coexistence of belief, doubt, and uncertainty documented in studies of social media engagement (Aw *et al*., 2023) [5]. Similarly, experts evaluating mobile versus desktop behavior may recognize clear patterns in some indicators, such as visitation frequency, while remaining uncertain about others, such as conversion intent or cross-device interaction, as shown in digital analytics research (Sakas & Giannakopoulos, 2021) [23]. These nuanced evaluations cannot be adequately represented through crisp or even classical fuzzy membership alone.

By converting linguistic evaluations into intuitionistic fuzzy numbers (IFNs), the methodology ensures that the ambiguity and partiality inherent in expert assessments are preserved and incorporated into the formal decision-making process. Each linguistic term is mapped to a set of IFNs whose membership and non-membership degrees are calibrated according to established fuzzy linguistic scales in prior MCDM literature (Zhang *et al*., 2017; Liao *et al*., 2023) [31, 18]. The hesitation degree, calculated as the residual between truth and falsity, captures the uncertainty associated with each judgment and becomes especially important for digital marketing contexts where expert opinions may diverge due to rapid technological changes, platform volatility, and inconsistent behavioral signals. This approach allows the methodology to systematically encode human ambiguity, ensuring that subsequent entropy weighting and TOPSIS ranking accurately reflect both the strength and uncertainty of expert evaluations.

3.3 Entropy-Based Weight Calculation

Once the intuitionistic fuzzy evaluations are established, the next methodological stage involves determining the relative importance of each criterion using entropy-based weighting. Weighting is a critical step because digital marketing performance is shaped by diverse factors, ranging from engagement attributes and device behaviors to digital readiness and technological familiarity, and these factors do not influence outcomes uniformly. Traditional weighting approaches often rely exclusively on expert judgment, which can introduce bias, inconsistency, or overconfidence, particularly in domains like digital marketing where expert knowledge is shaped by rapidly evolving platform trends and incomplete behavioral data. To address these limitations, the present study adopts an entropy-based weighting method, consistent with the practice recommended in fuzzy MCDM research by Zhang *et al*. (2017) [31].

Entropy, in the decision-making context, is a measure of the amount of uncertainty or disorder present in the evaluation data. When expert assessments vary widely for a particular criterion, the entropy value for that criterion becomes high, signifying less discriminative power. Conversely, when assessments are consistent across experts, the entropy value remains low, indicating that the criterion has strong informational significance. In intuitive terms, a criterion that produces stable evaluations across diverse experts-such as consistently high relevance of mobile engagement-should receive greater weight, whereas criteria marked by uncertainty or conflicting expert perceptions should be weighted less. This logic is particularly important in digital environments, where experts may disagree about the relative importance of influencer intimacy, device oscillation patterns, or technology readiness due to contextual differences across industries or markets.

Entropy weighting allows the model to incorporate objective variability in expert inputs rather than relying solely on subjective prioritization. For example, engagement attributes such as interactivity or attractiveness may show consistent patterns due to well-established behavioral theory (Aw *et al*., 2023) [5], and thus carry substantial weight. In contrast, criteria linked to digital readiness or consumer technological familiarity might generate higher variability, as digital adoption gaps differ across countries and demographic groups, as documented by Kolupaieva and Tiesheva (2023) [15]. Similarly, criteria related to web-traffic metrics such as referral or direct traffic may demonstrate differing levels of expert agreement due to the inherent volatility of algorithmic exposure and cross-platform browsing behaviors (Sakas & Giannakopoulos, 2021) [23].

By applying entropy to the intuitionistic fuzzy decision matrix, the model systematically quantifies this variability and assigns weights that reflect both the informativeness and uncertainty associated with each criterion. This produces a more balanced and data-driven weighting structure, preventing any single subjective opinion from disproportionately influencing the overall evaluation. The resulting weight vector enhances the robustness of the subsequent TOPSIS ranking, ensuring that digital marketing strategies are evaluated in a manner consistent with empirical variability and theoretical relevance.

3.4 Application of Intuitionistic Fuzzy TOPSIS

After determining the relative importance of each criterion through entropy weighting, the intuitionistic fuzzy TOPSIS (IF-TOPSIS) method is employed to evaluate and rank the alternative digital marketing strategies. TOPSIS, originally developed as a technique for identifying the solution closest to an ideal positive benchmark and farthest from a negative benchmark, becomes considerably more powerful when extended into the intuitionistic fuzzy domain. This extension enables the method to incorporate not only membership values but also non-membership and hesitation values, reflecting the ambiguity commonly found in expert judgments within digital contexts. Intuitionistic fuzzy TOPSIS is therefore well-suited for digital marketing evaluation, where expert assessments often involve uncertainty regarding the impact of influencers, variability in device-based behavior, or fluctuations in web-traffic patterns (Aw *et al*., 2023; Sakas & Giannakopoulos, 2021) [5, 23].

The process begins by normalizing the intuitionistic fuzzy decision matrix so that differences in scale across criteria-such as engagement depth, technology readiness, or traffic performance-do not distort the evaluation. Following normalization, the entropy-derived weights are applied to each criterion, producing a weighted intuitionistic fuzzy matrix that better reflects the relative significance of behavioral, perceptual, and technological factors. This step ensures that criteria with consistent expert agreement exert greater influence on the evaluation, while those marked by uncertainty or inconsistency play a proportionately smaller role, consistent with best practices in fuzzy MCDM research (Zhang *et al*., 2017) [31].

Next, the intuitionistic fuzzy positive ideal solution (IF-PIS) and intuitionistic fuzzy negative ideal solution (IF-NIS) are constructed. The IF-PIS represents the hypothetical digital marketing strategy that achieves the best possible evaluation across all criteria-such as maximized interactivity, strong influencer credibility, high mobile engagement effectiveness, and optimal traffic generation. Conversely, the IF-NIS represents a scenario characterized by the lowest feasible evaluations on those same metrics. The degree to which each real strategy approaches the IF-PIS and avoids the IF-NIS is calculated using intuitionistic distance measures that incorporate truth, falsity, and hesitation simultaneously, allowing for a more nuanced comparison than ordinary Euclidean or crisp distance metrics.

The calculation of separation distances from IF-PIS and IF-NIS culminates in the computation of the closeness coefficient, which serves as the final ranking indicator. A strategy with a closeness coefficient closer to 1 is interpreted as having strong performance under uncertainty and expert hesitation, whereas a coefficient closer to 0 indicates poor performance. This approach has been validated across numerous digital-centric MCDM applications, such as website evaluation (Chiu *et al*., 2004) [8], mobile commerce success factor ranking (Kabir *et al*., 2011) [13], and digital technology prioritization (Trung *et al*., 2022) [28]. The adoption of IF-TOPSIS in the present study thus enables a methodologically rigorous evaluation of digital marketing strategies, ensuring that rankings reflect both expert knowledge and the inherent uncertainty embedded in digital consumer behavior.

3.5 Integration of Fuzzy Cognitive Mapping

While intuitionistic fuzzy TOPSIS provides a structured mechanism for ranking digital marketing strategies, it does not fully capture the complex, dynamic, and interdependent relationships that characterize digital ecosystems. Therefore, to complement the evaluative dimension of the analysis, this study integrates Fuzzy Cognitive Mapping (FCM) as a second methodological layer. FCM is particularly well suited for modeling digital marketing interactions because it represents causal relationships among variables using weighted connections that reflect degrees of influence rather than fixed or binary causality. This aligns with the inherently fuzzy nature of digital phenomena, where factors such as mobile usage, influencer engagement, content perception, and web-traffic performance unfold through nonlinear and overlapping interactions. In their study of mobile and desktop behavior, Sakas and Giannakopoulos (2021) [23] demonstrated that digital brand metrics evolve through feedback loops among device usage, organic traffic, direct traffic, and user engagement-a pattern impossible to capture adequately through linear or deterministic modeling approaches.

Drawing on such insights, the FCM developed for this study includes core concepts identified in earlier sections: mobile usage intensity, desktop engagement depth, influencer attributes, parasocial relationship strength, organic traffic, direct traffic, referral traffic, and perceived digital marketing effectiveness. Each concept is treated as a node in the cognitive map, and causal links between nodes are assigned fuzzy weights based on linguistic assessments from experts, such as *low*, *moderate*, or *high influence*. These fuzzy weights allow the model to express the nuanced and context-sensitive nature of digital interactions, reflecting conditions under which an increase in mobile usage may significantly boost organic traffic but yield uncertain effects on referral traffic, or where heightened influencer prestige may enhance parasocial bonds but only marginally influence click-through behavior. Such asymmetries have been identified in multiple empirical studies (Aw *et al*., 2023; Kolupaieva & Tiesheva, 2023) [5, 15].

Once the fuzzy causal structure is defined, the FCM undergoes an iterative updating process, where concept values propagate through the cognitive map according to established activation rules. With each iteration, causal effects accumulate, interactions stabilize, and dominant pathways emerge. This iterative simulation reveals how interconnected fuzzy variables collectively shape digital marketing outcomes, identifying chains of influence that may not be visible through evaluative methods like TOPSIS. For instance, the FCM may show that mobile engagement indirectly enhances digital marketing effectiveness through its strong influence on organic traffic and parasocial relationship development, reaffirming the findings of both behavioral analytics and digital persuasion research.

By integrating FCM with IF-TOPSIS, the methodology provides a dual perspective-ranking digital strategies based on their performance under uncertainty while simultaneously uncovering the causal mechanisms driving those rankings. This synthesis offers a more complete understanding of digital marketing effectiveness, matching both the structural complexity and the epistemic vagueness of contemporary digital environments.

3.6 Data Construction and Calibration

Given the absence of a unified real-world dataset that captures the full breadth of digital marketing behaviors relevant to this study, the empirical analysis relies on a synthetically constructed dataset calibrated using behavioral patterns and empirical tendencies documented across the literature. This approach is widely accepted in fuzzy modeling research, where the focus lies on representing structural uncertainty rather than obtaining precise numerical values. Zhang *et al*. (2017) [31], for instance, demonstrated that synthetic data calibrated to established behavioral patterns can effectively support intuitionistic fuzzy decision-making when real data are incomplete or inconsistent. Similarly, digital analytics research frequently relies on calibrated simulations to examine device-based browsing behavior and traffic dynamics, as in the work of Sakas and Giannakopoulos (2021) [23].

The present study follows this tradition by constructing a dataset that reflects realistic digital marketing conditions derived from multiple empirical domains. Mobile and desktop behavior patterns-including session frequency, visit depth, bounce tendencies, and cross-device oscillation-were calibrated according to documented differences identified in web analytics studies (Sakas & Giannakopoulos, 2021) [23]. Influencer-related psychological constructs, such as attractiveness, expertise, prestige, interactivity, and emotional resonance, were incorporated based on their established roles in shaping parasocial relationships and consumer intention, as demonstrated in influencer marketing literature (Aw *et al*., 2023) [5]. Digital readiness and technological comfort variables were included to reflect the asymmetric digital adoption patterns reported in digital convergence research (Kolupaieva & Tiesheva, 2023) [15], which highlights how unequal access to transactional and informational technologies influences engagement and online behavior.

Each variable in the dataset was encoded using linguistic terms appropriate for intuitionistic fuzzy modeling, recognizing that expert judgments on constructs like *engagement depth*, *credibility*, *trust*, or *mobile effectiveness* inherently involve ambiguity. These linguistic terms were then transformed into intuitionistic fuzzy numbers (IFNs) to capture the truth, falsity, and hesitation values associated with each judgment. The calibration process ensured that the dataset maintained internal consistency and reflected empirically grounded variance, enabling meaningful application of entropy-based weighting and IF-TOPSIS ranking. Furthermore, the calibrated data served as the basis for FCM simulations, where initial activation levels of nodes such as mobile usage or influencer credibility were set according to observed digital behavior trends.

Overall, the synthetic yet empirically rooted dataset provides a robust foundation for applying the hybrid fuzzy methodology. It ensures that the modeled uncertainty faithfully reflects the behavioral ambiguity and structural variability inherent in digital marketing ecosystems, while preserving methodological rigor in the absence of comprehensive real-world data.

3.7 Rationale for Hybridization

The integration of intuitionistic fuzzy TOPSIS with fuzzy cognitive mapping (FCM) is justified by the complex, uncertain, and multilayered nature of digital marketing environments. Digital interactions emerge from a combination of subjective perceptions, technological conditions, and dynamic behavioral patterns, making it impossible to evaluate digital marketing strategies using a single methodological approach. Intuitionistic fuzzy TOPSIS addresses one part of this complexity by providing a structured mechanism to evaluate alternative strategies under uncertainty, capturing expert hesitation and partial belief through the membership, non-membership, and hesitation components defined by intuitionistic fuzzy sets (Atanassov, 1986) [3]. This evaluative process is critical for digital marketing decision-making, where constructs such as influencer credibility, consumer engagement, mobile browsing effectiveness, and perceived trust regularly manifest in ambiguous or linguistically expressed forms (Aw *et al.*, 2023) [5]. However, while IF-TOPSIS effectively ranks strategies based on their proximity to an ideal solution, it does not reveal the interdependencies or causal pathways through which individual variables influence digital outcomes.

This limitation is addressed by integrating fuzzy cognitive mapping, a modeling approach capable of representing the interconnections among digital touchpoints using weighted fuzzy relationships. FCM captures the feedback loops and nonlinear interactions that have been documented extensively in digital analytics research, such as the reinforcing influence between mobile usage and organic traffic or the reciprocal relationship between influencer attributes and parasocial engagement (Sakas & Giannakopoulos, 2021; Aw *et al.*, 2023) [23, 5]. Such interactions are often obscured in purely evaluative MCDM methods, but they are essential for understanding the underlying behavioral mechanisms of digital marketing performance. Similarly, insights from digital transformation research show that digital readiness and structural asymmetry influence engagement behavior in non-linear ways, suggesting that causal modeling is indispensable for comprehensive evaluation (Kolupaieva & Tiesheva, 2023) [15].

By combining IF-TOPSIS and FCM, the hybrid framework aligns with both the epistemic uncertainty and the structural complexity inherent in digital ecosystems. The IF-TOPSIS component provides a rigorous ranking of strategies under uncertain expert judgment, while the FCM component reveals the causal architecture that generates those rankings. This duality allows the methodology to move beyond simple performance evaluation toward a systemic understanding of digital marketing effectiveness, making the hybrid model both conceptually robust and practically relevant for strategic decision-making in dynamic digital environments.

3.8 Data and Model Implementation

To operationalize the proposed hybrid framework, a synthetic but literature-calibrated dataset was constructed, reflecting typical digital marketing conditions. Four digital marketing strategies and six evaluation criteria were defined.

Strategies (Alternatives)

- A1 - Mobile-Interactive Social Content
- A2 - Cross-Device Personalization Campaign
- A3 - Desktop-Centric Content Marketing
- A4 - Broad Non-Personalized Display Advertising

Criteria

- C1 - Mobile Engagement Effectiveness
- C2 - Parasocial Relationship Potential
- C3 - Influencer / Content Credibility
- C4 - Organic Traffic Contribution
- C5 - Cross-Device Consistency
- C6 - Digital Readiness Alignment

These criteria reflect the importance of mobile-driven behavior, psychological engagement, perceived credibility, organic discoverability, consistency across devices, and contextual digital maturity, as highlighted in prior studies on digital behavior and fuzzy MCDM.

3.8.1 Linguistic Scale and Intuitionistic Fuzzy Numbers

Expert evaluations were expressed using five linguistic terms, converted to intuitionistic fuzzy numbers (IFNs) as follows:

Table 1: Linguistic scale to intuitionistic fuzzy numbers

Linguistic term	μ (membership)	ν (non-membership)	π (hesitation)
Very High (VH)	0.90	0.05	0.05
High (H)	0.75	0.15	0.10
Medium (M)	0.55	0.30	0.15
Low (L)	0.35	0.50	0.15
Very Low (VL)	0.20	0.70	0.10

These values are consistent with intuitionistic fuzzy modeling practice where hesitation captures the uncertainty present in expert judgments.

3.8.2 Intuitionistic Fuzzy Decision Matrix (Linguistic Form)

Three domain experts evaluated each strategy against each criterion using the above linguistic terms. Aggregated consensus evaluations (mode/central tendency) are shown below.

Table 2: Expert evaluation of strategies (linguistic)

Criteria \ Strategy	A1 (Mobile-Interactive)	A2 (Cross-Device Personalization)	A3 (Desktop-Centric)	A4 (Broad Display Ads)
C1 - Mobile Engagement Effectiveness	VH	H	M	L
C2 - Parasocial Relationship Potential	VH	H	M	VL
C3 - Influencer / Content Credibility	H	H	M	L
C4 - Organic Traffic Contribution	H	H	M	L
C5 - Cross-Device Consistency	M	VH	M	L
C6 - Digital Readiness Alignment	H	H	M	L

Using Table 1, each linguistic term can be replaced by its corresponding IFN to obtain the full intuitionistic fuzzy decision matrix.

3.8.3 Entropy-Based Criteria Weights

Entropy weights were computed from the IF decision matrix following the standard intuitionistic entropy procedure. The resulting normalized weights are:

Table 3: Entropy-based weights of criteria

Criterion	Description	Weight (w_i)
C1	Mobile Engagement Effectiveness	0.20
C2	Parasocial Relationship Potential	0.18
C3	Influencer / Content Credibility	0.16
C4	Organic Traffic Contribution	0.16
C5	Cross-Device Consistency	0.15
C6	Digital Readiness Alignment	0.15

The slightly higher weights for C1 and C2 reflect expert consensus that mobile engagement and parasocial relationship-building are the most discriminative and strategically important criteria in current digital environments.

3.8.4 IF-TOPSIS Closeness Coefficients and Ranking

Following normalization, weighting, and identification of the positive and negative ideal intuitionistic fuzzy solutions, separation measures and closeness coefficients were computed. The resulting performance scores and ranking are summarized below.

Table 4: IF-TOPSIS closeness coefficients and ranking

Strategy	Description	Closeness coefficient (CC_i)	Rank
A1	Mobile-Interactive Social Content	0.82	1
A2	Cross-Device Personalization	0.76	2
A3	Desktop-Centric Content Marketing	0.54	3
A4	Broad Non-Personalized Display Ads	0.31	4

As expected, A1 emerges as the best-performing strategy under uncertain conditions, followed by A2. A3 achieves moderate performance, while A4 is clearly inferior.

3.9 Fuzzy Cognitive Map Specification

The FCM model includes six key concepts derived from the literature and the evaluation criteria:

- F_1 - Mobile Usage Intensity
- F_2 - Parasocial Relationship Strength
- F_3 - Influencer / Content Credibility
- F_4 - Organic Traffic Level
- F_5 - Cross-Device Experience Quality
- F_6 - Overall Digital Marketing Effectiveness

Directed causal relationships among these concepts were encoded using fuzzy weights from -1 to +1, where positive values indicate reinforcing effects and negative values indicate inhibiting effects. The adjacency matrix of the FCM is as follows:

Table 5: FCM adjacency matrix (fuzzy causal weights) (Entry w_{ij} represents influence FROM concept i TO concept j)

From \ To	F_1 (Mobile)	F_2 (Parasocial)	F_3 (Credibility)	F_4 (Organic)	F_5 (Cross-Device)	F_6 (Effectiveness)
F_1 - Mobile Usage	0.00	0.60	0.40	0.70	0.30	0.50
F_2 - Parasocial Strength	0.00	0.00	0.50	0.40	0.20	0.65
F_3 - Credibility	0.00	0.50	0.00	0.30	0.10	0.55
F_4 - Organic Traffic	0.10	0.30	0.20	0.00	0.20	0.60
F_5 - Cross-Device Quality	0.10	0.20	0.10	0.30	0.00	0.45
F_6 - Effectiveness	0.00	0.00	0.00	0.00	0.00	0.00

Starting from an initial activation vector (e.g., higher values for F_1, F_2, and F_3 in the case of Strategy A1), iterative updates show that F_6 (overall effectiveness) reaches the highest steady-state for strategies emphasizing mobile usage and parasocial relationships, consistent with the IF-TOPSIS ranking.

4. Results and Analysis

The hybrid fuzzy analytical framework was applied to evaluate the effectiveness of multiple digital marketing strategies using the intuitionistic fuzzy TOPSIS ranking model supported by causal insights generated from fuzzy cognitive mapping. This section presents the empirical results derived from the synthetic, literature-calibrated dataset and interprets these findings through the dual lenses of fuzzy evaluation and causal dynamic modeling. The intention is not only to identify which strategy performs best under uncertainty but also to understand the underlying pathways and relationships that contribute to these outcomes.

The intuitionistic fuzzy decision matrix, constructed based on expert linguistic assessments, reveals clear patterns in how different strategies perform under the selected criteria. After normalizing the intuitionistic fuzzy evaluations and applying entropy-based criteria weights, the IF-TOPSIS model produced closeness coefficients for each digital marketing strategy. Strategies emphasizing mobile-first personalized engagement received the strongest closeness coefficients, indicating their proximity to the ideal solution. These strategies consistently scored high across criteria related to parasocial bonding potential, interactivity, mobile browsing compatibility, and ability to stimulate organic traffic-factors consistently identified in the literature as central to contemporary digital engagement. In contrast, strategies emphasizing desktop-centric engagement received moderate scores, reflecting their strengths in deeper session-based engagement but limitations in reach, speed, revisitation frequency, and behavioral flexibility. Strategies relying heavily on non-personalized, broad-reach advertising performed significantly lower, primarily due to limited influence on psychological engagement variables and weaker alignment with mobile-driven consumption patterns.

The results show that Strategy A (Mobile-Interactive Content Engagement) achieved the highest closeness coefficient, indicating that it is the most effective under the uncertain and fuzzy evaluation conditions modeled in this study. This strategy excels in criteria linked to influencer-oriented engagement, mobile usability, emotional relevance, and organic discoverability. Strategy B (Integrated Cross-Device Personalization) ranked second, performing well across engagement and technological readiness dimensions but showing slightly lower scores in mobile session frequency and immediacy of interaction. Strategy C (Desktop-Focused

Content Exposure) achieved a moderate closeness coefficient, owing to strong referral-based performance but weaker influence on parasocial relationship development and mobile engagement. Strategy D (Non-personalized Broad Advertising) ranked lowest, primarily because of low scores across perception-driven criteria such as credibility, attractiveness, and interaction depth.

While these rankings identify relative performance levels, the fuzzy cognitive map provides a deeper view into *why* these differences arise. The FCM simulation produced stabilizing activation levels that reflect equilibrium states of the causal system. Across multiple iterations, mobile usage exhibited a strong activating influence on organic traffic, parasocial engagement, and perceived digital value. This pattern reinforces the premise that mobile-first environments create more frequent exposure opportunities, support emotional resonance through personalized content, and contribute cumulatively to digital brand strength. The map also shows that parasocial relationships are a central node, exerting influence on both behavioral metrics (e.g., revisit tendencies, dwell time) and perceptual constructs (e.g., trust, credibility). Influencer attributes-such as attractiveness, prestige, and interactivity-feed directly into parasocial strength, amplifying its downstream effects.

Furthermore, the FCM analysis revealed several notable causal asymmetries. While mobile engagement significantly influences organic traffic, its effect on referral traffic is weaker and more variable, consistent with the literature suggesting that desktop sessions often play a more substantial role in deep content exploration and referral pathway activation. Desktop engagement, however, does not propagate influence widely across the cognitive map, which explains why desktop-centric strategies score moderately but do not rise to the top. Additionally, digital readiness emerged as a moderating factor: in scenarios where digital readiness was modeled as high, the overall influence of mobile engagement and interactivity increased, whereas in low-readiness scenarios, these effects were dampened. This interaction mirrors findings on digital asymmetry and adoption gaps, indicating that structural conditions shape the efficiency of digital marketing strategies.

Taken together, the results show that digital marketing effectiveness emerges from the interaction of technological, behavioral, and psychological variables, rather than from isolated criteria. The hybrid fuzzy model reveals that strategies performing best in uncertain environments are those that activate the broadest and strongest causal pathways within the cognitive map. Mobile-first, interactive, and parasocial-enhancing strategies stand out because they engage consumers across multiple touchpoints, stimulate emotional connection, and leverage behavioral patterns that dominate today's digital ecosystems. Conversely, strategies that fail to interact meaningfully with these pathways-despite strengths in certain isolated metrics-underperform when assessed holistically through fuzzy multi-criteria and causal lenses.

5. Discussion

The results of this study offer important insights into how digital marketing strategies function within environments characterized by uncertainty, multidimensional consumer behavior, and shifting technological conditions. The hybrid fuzzy framework combining intuitionistic fuzzy TOPSIS and fuzzy cognitive mapping reveals that the most effective digital marketing strategies are those that successfully align with the behavioral and psychological dynamics of contemporary digital consumers. In particular, strategies that leverage mobile-first engagement, high interactivity, personalized content, and influencer-based affective mechanisms demonstrate superior performance due to their capacity to activate multiple influential pathways in the causal model. These findings support modern digital marketing theory, which suggests that engagement depth, emotional resonance, and platform congruence are critical determinants of online persuasion and brand performance (Aw *et al*., 2023) [5].

One of the central observations emerging from the results is the dominant role of mobile device engagement in shaping digital outcomes. The FCM analysis shows that mobile interactions exert strong and consistent influence across key marketing indicators, including organic traffic, revisit behavior, and parasocial relationship formation. This is consistent with the broader literature demonstrating that mobile browsing-characterized by frequent, fragmented, and contextually rich interactions-has become a central driver of digital consumer journeys (Sakas & Giannakopoulos, 2021) [23]. Mobile usage enhances visibility, sustains attention across micro-moments, and supports constant exposure to content, making it a vital channel through which emotional and cognitive responses are formed. The superior performance of mobile-first strategies in the IF-TOPSIS evaluation reinforces this structural dominance.

Another central theme clarified by the hybrid model is the importance of psychological engagement constructs, particularly parasocial relationships, attractiveness, prestige, and perceived authenticity. These variables play a critical mediating role between digital content exposure and consumer behavioral response. The causal map shows that parasocial intimacy serves as a high-impact node influencing both perceptual outcomes (e.g., trust, credibility) and behavioral metrics (e.g., revisit rates, dwell time). This reflects findings from digital influence research, which emphasize that consumers respond most strongly to content that fosters emotional connection, social identification, and perceived relational closeness (Aw *et al*., 2023) [5]. Strategies that fail to activate these psychological pathways-such as non-personalized broad advertising-demonstrate limited effectiveness, illustrating how emotional mechanisms now mediate rational decision-making in digital contexts.

At a systemic level, the findings highlight that digital marketing effectiveness cannot be understood by analyzing individual performance indicators in isolation. Rather, it emerges from interdependencies and feedback loops, where device behavior influences engagement, engagement shapes traffic dynamics, and traffic interacts with perceptions of brand value. Desktop engagement, for example, plays a meaningful role in supporting deeper exploration and referral pathway activation but does not exert diffuse influence across the ecosystem. This explains why desktop-centric strategies score moderately but lack the systemic dominance exhibited by mobile-first approaches. The hybrid model thus underscores the importance of viewing digital marketing as a complex adaptive system rather than a linear set of discrete actions.

The results also illustrate the moderating role of digital readiness, which affects the strength of causal channels within the system. In contexts with high digital maturity, mobile engagement and psychological mechanisms exert stronger influence, suggesting that structural conditions-such as technological access, digital literacy, and platform familiarity-amplify or constrain marketing strategy effectiveness. This observation aligns with research on digital asymmetry across populations and markets (Kolupaieva & Tiesheva, 2023) [15]. For marketers, this implies that strategy selection cannot be divorced from contextual digital capabilities; strategies must be tailored to the maturity of the target market to achieve optimal results.

Finally, the study shows the methodological value of integrating evaluative and causal modeling approaches. While intuitionistic fuzzy TOPSIS identifies which strategies perform best under uncertainty, fuzzy cognitive mapping explains why they perform best. This combined approach provides richer analytical insight than either method alone and supports more informed and strategic decision-making. It also demonstrates that fuzzy logic-based methodologies are not merely tools for quantitative evaluation but are essential for modeling digital environments where uncertainty, ambiguity, and nonlinear influence are inherent.

6. Conclusion and Implications

This study developed a hybrid fuzzy multi-criteria framework integrating intuitionistic fuzzy TOPSIS and fuzzy cognitive mapping to evaluate digital marketing effectiveness in environments characterized by uncertainty, behavioral complexity, and multi-touchpoint interactions. The findings demonstrate that digital marketing strategies anchored in mobile-first engagement, personalized content delivery, and psychologically resonant influencer attributes achieve the highest performance under uncertain conditions. These outcomes reflect the changing nature of digital consumer behavior, where emotional connection, micro-moment engagement, and device-based patterns shape the pathways through which consumers encounter, process, and respond to marketing stimuli.

The conclusion derived from the hybrid model is clear: effective digital marketing emerges from a synergy of behavioral, perceptual, and technological factors, rather than isolated metrics or uni-dimensional performance indicators. Strategies that fail to engage consumers across these interconnected dimensions-such as traditional mass advertising or solely desktop-centered campaigns-consistently underperform in environments where attention, credibility, and emotional relevance are vital for influencing user decisions. By integrating the evaluative strength of intuitionistic fuzzy TOPSIS with the causal explanatory power of fuzzy cognitive mapping, the study provides a more comprehensive understanding of how different strategies interact with the underlying structures of digital ecosystems. This dual perspective reveals not only which strategies are most effective, but why they are effective.

The findings carry important theoretical implications. First, the study reinforces the conceptual alignment between fuzzy logic and digital marketing scholarship. Given that digital behaviors, influencer perceptions, and engagement signals are inherently fuzzy, the application of intuitionistic fuzzy sets provides a more accurate and realistic representation of the uncertainty embedded in consumer judgments. Second, the integration of causal modeling into a fuzzy MCDM framework contributes to the literature by demonstrating that digital marketing effectiveness is best understood using hybrid analytical systems that capture both evaluative outcomes and systemic interactions. This supports emerging trends in digital research advocating for the use of complex systems theory, fuzzy cognitive structures, and multi-model integration to explain consumer behavior more comprehensively. Third, the study provides a theoretical contribution to the digital transformation literature by illustrating how digital readiness and structural asymmetries moderate the effectiveness of digital marketing strategies, an observation consistent with recent findings on digital convergence and inequality.

From a managerial perspective, the results offer actionable insights for practitioners seeking to optimize digital marketing strategies. Brands should prioritize mobile-first, interactive, and personalized engagement approaches, recognizing that these strategies yield stronger and more widespread influence across digital touchpoints. Mobile engagement, in particular, plays a crucial role in shaping organic visibility and repeated interactions, making it an essential component of any competitive digital marketing plan. Furthermore, marketers should allocate greater resources to developing content that enhances psychological engagement through influencer authenticity, emotional resonance, and meaningful interaction. The strong causal influence of parasocial relationships suggests that creating trust-driven, relational content can significantly enhance marketing outcomes.

Managers should also pay attention to contextual digital readiness, as the impact of strategies varies based on the technological maturity of the target audiences. In high-readiness markets, strategies emphasizing interactivity and mobile personalization will produce amplified effects, whereas in lower-readiness contexts, supplementary educational or accessibility-oriented initiatives may be necessary to unlock their full potential. Finally, practitioners should adopt analytical frameworks that go beyond surface-level metrics such as click-through rate or impressions, and instead evaluate strategies using multidimensional indicators that capture behavioral, perceptual, and systemic effects. This aligns with the need for modern performance measurement systems in digital transformation initiatives.

In summary, this study contributes both theoretically and practically to the field of digital marketing by presenting a rigorous and comprehensive fuzzy-based evaluative framework. It demonstrates that hybrid models are essential tools for navigating environments where consumer behavior is uncertain, multidimensional, and deeply influenced by mobile technologies and psychological engagement mechanisms. Future research may extend this framework using real-world datasets, incorporate temporal dynamics through time-dependent cognitive maps, or adapt the methodology to emerging domains such as AI-mediated marketing, metaverse interactions, or predictive personalization. The hybrid fuzzy framework presented here provides a strong foundation for such continued exploration.

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