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OPTIMIZING CONTENT MARKETING STRATEGIES BASED ON SEARCH ENGINE ALGORITHMS AND ARTIFICIAL INTELLIGENCE TO INCREASE SEMANTIC RELEVANCE AND SEO EFFECTIVENESS

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ABSTRACT

The integration of generative AI into search engine algorithms presents fundamental challenges for contemporary content marketing strategies. This study aims to quantify the impact of artificial intelligence on SEO performance and to develop a composite index system for optimizing content marketing in AI-driven search environments. This study employs content analysis of secondary data from leading industry platforms. In addition, the current research identifies interdependencies among key performance metrics and applies multifactor aggregation using min–max normalization. Predictive modeling is used to assess AI adoption trajectories, accounting for the volatility associated with the rollout of AI Overviews. The analysis includes an interregional comparative assessment of the United States and the European Union, incorporating institutional differences in antitrust regulation. The empirical dataset comprises more than 300,000 keywords, over 10 million queries, and large-scale clickstream data from Semrush and Ahrefs spanning 2022–2025. The AI Search Transformation Index (ASTI = 0.547) indicates a moderate level of adaptation of the search ecosystem to generative AI. The PEAIO visibility loss ratio (34.74%) captures a substantial decline in organic click-through rates for top-10 positions attributable to AI Overviews. In the US, the Traffic Redistribution Index (TRI) declined by 15.3% reflecting increased click migration toward Google-owned properties and a rise in zero-click searches to 58.5%. An AI citation anomaly was identified, whereby pages ranking in positions 21–50 exhibit a 64.7% higher likelihood of being cited in AI-generated responses than those in the top five results. The composite Global Score of 56.5 suggests moderate market readiness for AI-dominated search, alongside relatively high elasticity in retaining organic traffic. The proposed methodology enables systematic diagnostics of SEO vulnerabilities, cross-regional benchmarking of content strategies as well as the development of data-driven optimization frameworks. Strategic implications include adopting hybrid positioning strategies that balance traditional CTR optimization with AI citation visibility. Thereby it entails increasing semantic content density and diversifying traffic acquisition through platforms with higher AI citation propensity.

Keywords: *AI SEO Transformation, Semantic Relevance, AI Overviews, Zero-Click Searches, Organic Visibility, Content Marketing, Composite Indexes.*

1. INTRODUCTION

The digital transformation of search engines driven by the integration of generative artificial intelligence is fundamentally reshaping the content marketing landscape. A principal problem addressed in this study is the substantial decline in organic click-through rates (CTR) following the introduction of AI Overviews, combined with the absence of a comprehensive methodology for evaluating the impact of AI on SEO performance. According to Semrush [1, 2], the penetration of AI Overviews

increased from 6.49% in January to 15.69% in November 2025. Simultaneously, research by SparkToro [3] and Datos [3] indicates that zero-click searches now account for 58.5–59.7% of total search activity. Existing literature highlights the growing importance of semantic relevance in AI-driven information retrieval systems. For instance, Wang et al. [4] demonstrate the critical role of semantic relevance through pseudo-relevance feedback mechanisms, underscoring the need to adapt content strategies to AI-based ranking and response-generation algorithms. In this light, Alazzam et al. [5] further emphasize the importance of developing structured information models for e-commerce platforms within the broader context of global digitalization.

As a result, semantic relevance has emerged as a decisive factor in content positioning within AI-generated search engine responses. Al-Buraihy and Wang [6] propose a multimodal approach to semantic alignment in cross-language image description, illustrating the transferability of optimization principles across diverse content modalities. Empirical evidence from Ahrefs [7] shows that the presence of AI Overviews reduces the CTR of top-ranking results by 34.5%, while pages ranked beyond the top 20 exhibit a higher probability of being cited in AI-generated answers.

The ongoing transformation of the search ecosystem introduces significant challenges, including intensified competition and the need to adapt content strategies in e-commerce and digital marketing. It is of note that Mironova et al. [8] stress the importance of modeling innovative enterprise strategies under conditions of rapid technological change. Accordingly, SE Ranking [9] reports a 58% increase in competitive intensity within the SEO industry attributable to AI adoption. Similarly, Adobe Analytics [10] identifies a 1300% increase in AI-driven search conversions during 2024, characterized by higher conversion efficiency. These dynamics accentuate the necessity of developing comprehensive methodological frameworks for evaluating content marketing effectiveness in an AI-dominated search environment.

Despite growing scholarly attention to AI-driven search transformation, a critical gap persists in the literature. Existing studies predominantly examine isolated aspects of SEO optimization-such as technical frameworks [11–13], e-commerce applications [14–16], or historical evolution [17]-without providing integrated quantitative assessments of AI Overviews' impact on organic traffic dynamics. While Wang et al. [4] and Al-Buraihy and Wang [6] demonstrate the importance of semantic relevance in information retrieval, their work does not address how AI-generated search results alter traditional SEO metrics. Similarly, although Bansal [17] traces SEO evolution toward AI integration, no study to date has developed a composite index system to systematically quantify the multifactorial impact of generative AI on content visibility. This research addresses this gap by advancing the hypothesis that the impact of artificial intelligence on content visibility is non-linear and contingent upon both semantic relevance and SERP position. The scientific novelty lies in: (1) identifying an AI citation anomaly whereby lower-ranked pages (positions 21–50) exhibit higher citation probability in AI-generated responses than top-ranked results; (2) demonstrating the multifactorial nature of semantic relevance through empirical modeling of AI-driven search ecosystem transformation.

The purpose of this study is to quantify the impact of artificial intelligence on SEO performance and to develop a composite index system for optimizing content marketing strategies in AI-dominated search environments. To achieve this objective, the study addresses three research tasks: (1) Systematic data aggregation: to compile and systematize secondary data on AI-driven search transformation, organic traffic dynamics, and semantic relevance during 2022–2026, including AI Overviews penetration, zero-click search prevalence, and cross-channel traffic redistribution; (2) Index construction: to develop five composite indices-AI Search Transformation Index (ASTI), Position Erosion due to AI Overviews (PEAIO), Traffic Redistribution Index (TRI), Content Conversion Efficiency (CCE), and Algorithmic Content Relevance Index (ACRI)-along with an integral Global Score, using min–max normalization, weighted aggregation, and predictive modeling to assess SEO performance across multiple dimensions; (3) Strategic framework development: to formulate data-driven recommendations for adapting content marketing practices to AI-based search algorithms, enhancing semantic relevance, and maintaining organic visibility in the evolving search landscape.

2. LITERATURE REVIEW

The digital transformation of search engines and the integration of artificial intelligence into ranking algorithms have introduced new challenges for content marketing strategies. Contemporary SEO research can be classified into four distinct streams: (1) technical optimization of web frameworks, (2) AI impact on content visibility, (3) sector-specific e-

commerce applications, and (4) SME adaptation strategies.

However, a critical methodological gap persists: existing studies lack empirical quantification of AI Overviews' impact on organic traffic and fail to provide integrated frameworks for operationalizing semantic relevance within AI-dominated search environments. This gap is particularly pronounced in three dimensions: the absence of composite index systems for measuring AI-driven SEO transformation, limited understanding of non-linear relationships between SERP position and AI citation probability, and insufficient cross-regional comparative analysis of traffic redistribution patterns. Technical framework optimization studies demonstrate limited applicability to AI-driven search contexts. Tempariyawan et al. [11] compare the SEO performance of Laravel Blade and Laravel Inertia in the Indonesian context, contributing to framework-level optimization. Their analysis is fundamentally limited by pre-AI assumptions: it does not explain how JavaScript rendering affects indexing by AI-driven crawlers, nor does it address framework adaptability to AI Overviews-a critical omission given that AI crawlers prioritize semantic content extraction over traditional DOM rendering. Similarly, Kumar and Priya [12] analyze the SEO advantages of Next.js, emphasizing server-side rendering and automated metadata generation.

While valuable for traditional SEO, their study fails to recognize that AI-generated search responses rely on structured data schemas rather than merely rendered HTML-thus missing the opportunity to evaluate Next.js's Schema.org integration capabilities. Kowalczyk and Szandala [13] examine SEO performance in Single-Page Applications (SPA) versus Multi-Page Applications (MPA) from a technical perspective. Critically, their framework-centric approach overlooks content-level factors: the implications of SPA architectures for content citation by ChatGPT Search and other large language model (LLM)-based systems remain unaddressed, despite evidence that LLMs prioritize content chunking over URL structure. E-commerce SEO literature exhibits a temporal disconnect from AI-driven search realities.

Asrigo and Kaburuan [14] investigate improvements in e-commerce rankings using conventional SEO techniques but operate within an outdated paradigm: they do not consider zero-click searches or traffic displacement resulting from Google Shopping integration-phenomena that now account for 58.5–59.7% of total search activity [3]. This oversight renders their optimization recommendations potentially counterproductive in AI-augmented environments where traditional CTR metrics no longer correlate with visibility. Arinze and Onyinye [15] examine the role of digital marketing strategies in shaping the future of e-commerce with an emphasis on SEO; however, their conceptual approach lacks empirical grounding: the study provides no quantitative evaluation of how AI-based search alters conversion funnels and the return on investment of SEO initiatives, limiting its applicability to data-driven decision-making. Zakki et al. [16] assess the influence of content quality, SEO, and social media on the success of UMKM campaigns but fail to capture emergent dynamics: they do not explore the synergistic effects of cross-channel integration in the context of AI-generated recommendations, despite evidence that AI systems increasingly synthesize multi-source signals for response generation.

Conceptual and historical analyses provide valuable context but lack predictive power. Bansal [17] traces the historical evolution of SEO from its early stages to the era of artificial intelligence, offering important conceptual insights. Nevertheless, the study's retrospective focus limits its utility: it does not offer predictive models to forecast the future trajectory of SEO under the influence of generative AI and LLMs-a critical limitation given the exponential acceleration of AI adoption (AI Overviews penetration increased from 6.49% to 15.69% in just 10 months [1]).

Macumber and Pagadala [18] explore the use of artificial intelligence for content generation in e-commerce. However, their treatment of semantic relevance is superficial: they do not sufficiently explicate the mechanisms through which AI-generated content achieves high semantic relevance for search and retrieval algorithms, nor do they address potential trade-offs between content automation and semantic depth. Reyes-Lillo et al. [19] analyze visibility, discoverability, and Academic SEO in digital repositories, yet their domain-specific focus precludes generalization: empirical evidence on the effectiveness of academic SEO strategies for positioning in Google Scholar and AI-based assistants remains limited, and cross-domain applicability to commercial search contexts is unverified. SME and localized digital marketing research demonstrates geographic and temporal constraints. Simanjutak and Purba [20] examine the impact of SEO on MSME sales growth in Indonesia but their findings suffer from context dependency: the analysis is limited to a local context without addressing global AI search trends and their

implications-a significant limitation given that AI Overviews exhibit different adoption patterns across regions (US vs. EU).

Martiyanti et al. [21] describe SEO training programs for UMKM through practical workshops, but the absence of longitudinal evaluation fundamentally undermines their conclusions: insights into long-term effectiveness and adaptability to evolving search algorithms remain limited, and there is no validation of whether trained strategies remain effective post-AI integration. Josepina et al. [22] investigate SEO practices in online journalism to increase readership but overlook competitive displacement: they do not analyze competition between journalistic content and AI-generated summaries in zero-click search environments, despite evidence that AI Overviews reduce top-10 CTR by 34.74% [7].

Technical audit and meta-analytical studies reveal methodological limitations. Rachita [23] provides a comprehensive overview of SEO audits and optimization strategies with a strong emphasis on technical parameters. Still, the study's technical bias creates a critical blind spot: insufficient attention is paid to semantic relevance and adaptation to AI-based ranking mechanisms, which now constitute primary determinants of AI citation probability. Usmany et al. [24] conduct a meta-analysis of SEO performance in marketing based on multiple empirical studies. However, their temporal coverage creates an obsolescence risk: the review does not extend beyond 2023, preceding the large-scale adoption of AI Overviews-thus excluding the most transformative period in search engine history.

Ghazali and Isnain [25] demonstrate the effectiveness of the RankMath plugin for automated SEO optimization in WordPress environments. In this light, their tool-centric approach neglects strategic depth: no comparative analysis is offered between plugin-based automation and manual optimization strategies aimed at achieving AI citation in LLM-generated responses, and the study cannot address whether automation sacrifices semantic optimization for technical compliance.

Synthesis and gap identification reveals three critical deficiencies in existing literature: (1) Measurement gap: no study has developed composite indices that integrate AI Overviews penetration, zero-click dynamics, traffic redistribution, and semantic relevance into a unified assessment framework-existing research relies on isolated, non-comparable metrics. (2) Positional paradox: the literature assumes a monotonic relationship between SERP position and visibility, yet emerging evidence suggests non-linear patterns in AI citation behavior-this paradox remains unexamined and unquantified. (3) Methodological fragmentation: studies employ inconsistent data sources, timeframes, and geographic scopes, precluding cross-study synthesis and limiting the development of generalizable optimization frameworks. In contrast to existing research, the present study makes four distinct contributions: First, it develops a composite index system (ASTI, PEAIO, TRI, CCE, ACRI, Global Score) that enables systematic, multidimensional quantification of AI impact on SEO performance-addressing the measurement gap through min–max normalization and weighted aggregation of heterogeneous metrics. Second, it empirically identifies and quantifies an AI citation anomaly-demonstrating that positions 21–50 exhibit 64.7% higher citation probability than positions 1–5-thereby challenging fundamental assumptions about SERP optimization. Third, it provides cross-regional comparative analysis (US vs. EU) incorporating institutional differences in antitrust regulation, enabling context-sensitive strategic recommendations. Fourth, it integrates large-scale empirical data (300,000+ keywords, 10M+ queries, 2022–2025) with predictive modeling to forecast AI adoption trajectories-offering actionable insights for adapting content marketing strategies to an AI-dominated search landscape. These contributions position the study at the intersection of SEO analytics, AI-driven information retrieval, and data-driven marketing strategy, filling a critical void in both academic literature and industry practice.

3. METHODS

3.1. Research design

The study was conducted in four consecutive stages. At the first stage, data sources were selected based on domain authority criteria (Ahrefs Domain Rating > 85) and their citation frequency and representation within the top 10 SERP results for the key queries “SEO statistics” and “AI search impact.” Sources were chosen from industry analytics platforms (Semrush, Ahrefs, SE Ranking), research organizations (SparkToro, Datos) and specialized media outlets (Search Engine Land) that collectively shape methodological and empirical consensus within the SEO industry.

1. At the second stage, secondary data were systematized into five analytical categories: (1) AI-driven search transformation metrics, including the penetration of AI Overviews and changes in zero-

click search prevalence; (2) organic traffic indicators, such as position-based CTR and clicks to the open web; (3) AI-originated visitor characteristics, including conversion value and engagement metrics; (4) industry-level features, such as market saturation and competitive intensity; (5) semantic relevance indicators, operationalized through AI citation and referencing patterns.

2. At the third stage, an analytical sample of secondary data was constructed. The dataset comprises more than 300,000 keywords derived from Ahrefs and Semrush, over 10 million queries from the Semrush AI Overviews Study, more than 200,000 keywords used for zero-click analysis based on the Datos clickstream panel as well as aggregated statistics spanning 15 industry verticals. From this sample, key empirical outputs were extracted, including the dynamics of AI Overviews adoption (January–November 2025), CTR changes across positions 1–10, comparative traffic redistribution between the US and EU, industry-specific AI adoption patterns, and conversion performance metrics by content type.

3. At the fourth stage, a set of composite indices was calculated to quantify the impact of AI on SEO performance: ASTI (AI Search Traffic Index), measuring changes in organic traffic attributable to AI-driven search; PEAIO (Position Erosion due to AI Overviews), capturing visibility loss caused by AI Overviews; TRI (Traffic Retention Index), assessing the degree of organic traffic preservation; CCE (Content Citation Efficiency), evaluating the probability and effectiveness of content citation in AI-enhanced SERPs; ACRI (Algorithmic Content Relevance Index), measuring the semantic relevance of content within AI-based ranking and response-generation systems.

3.2. Data collection

The empirical base of the study comprises 34 sources, including peer-reviewed academic publications, industry analytical reports and large-scale empirical studies in the fields of SEO, content marketing, search engine algorithms and artificial intelligence during the period of 2022–2026. For the purposes of quantitative analysis, eight validated sources were selected (Table 1) based on the principle of methodological triangulation. These sources provide extensive statistical datasets and enable comparative assessment of the impact of AI-driven search mechanisms on SEO performance.

In addition, the empirical base includes 26 peer-reviewed academic publications published between 2024 and 2026. Those serve to establish the theoretical framework and methodological justification for analyzing the role of artificial intelligence in search engine algorithms and content optimization.

Table 1: Data sources and reach parameters

Source	Data type	Geography	Period	Sample size
Semrush	AI search impact, AI Overviews study	Global	2024–2025	10M+ queries, 500+ topics, 11K domains
Ahrefs	CTR reduction, GSC data	Global	2024–2025	300K keywords (150K AIO, 150K control)
SE Ranking	SEO / marketing statistics	Global	2025–2026	120+ metrics, proprietary datasets
SparkToro / Datos	Zero-click search, clickstream	US, EU	2022–2024	Tens of millions panelists, desktop + mobile
Search Engine Land	Desktop search behavior	US, EU, UK	Q1 2025	Traditional vs AI tools comparison
Digital Trends (Adobe)	AI search engagement	US retail	Holiday 2024	1+ trillion visits, 5K survey
Academic sources	SEO optimization, AI trends	Global	2024–2025	26 peer-reviewed papers

Source: consolidated by the author (based on [1–3, 7, 9, 10, 26, 27]

3.3. Methods

The assessment of source authority was conducted using Domain Rating criteria (Ahrefs DR > 85), complemented by SERP visibility and citation frequency across leading industry platforms. Content analysis of the selected reports involved the systematic extraction of key performance metrics and the construction of time series across five indicator categories. Basically, the dataset aggregation was performed using search volume filtering (SV > 100) and temporal consistency checks to ensure data validity for the period 2022–2026. Composite indices were calculated using min–max

normalization, geometric weight aggregation, and predictive modeling of AI adoption trajectories.

3.3.1. Data analysis

To quantify the impact of artificial intelligence on SEO performance, five composite indices and an integral Global Score were applied. These measures show the transformation of the search ecosystem, erosion of organic visibility, redistribution of traffic, content-level performance and positioning within AI-generated search results.

3.3.2. AI-SEO Transformation Index (ASTI)

Integrates AI Overviews change, zero-click dynamics, organic CTR drops, and AI visitor value:

$$ASTI = \sqrt[3]{\left(\alpha_1 \cdot \frac{\Delta AIO}{100}\right)^2 + \left(\alpha_2 \cdot \frac{\Delta ZC}{100}\right)^2 - \left(\alpha_3 \cdot \frac{\Delta OCTR}{100}\right)^2 + (\alpha_4 \cdot ln(VAIV))^2} \cdot K_{vol} \quad (1)$$

where ΔAIO is the change in the share of AI Overviews (p.p.), ΔZC is the change zero-click rate (p.p.), $\Delta OCTR$ is the change in organic CTR (p.p.), $VAIV$ is the relative value of the AI visitor, $\alpha_1 = 0.35, \alpha_2 = 0.25, \alpha_3 = 0.30, \alpha_4 = 0.10$, $K_{vol} = 1 + \frac{\sigma_{AIO}}{\bar{x}_{AIO}}$ is the volatility coefficient.

3.3.3. AI Overviews Position Performance Ratio (PEAIO)

Measures the relative decrease in CTR for the top 10 positions with a position penalty:

$$PEAIO_p = \left(\frac{CTR^p_{baseline} - CTR^p_{AIO}}{CTR^p_{baseline}}\right) \cdot 100 \cdot [1 + (p-1) \cdot \beta] \cdot \left(1 - \frac{SV}{SV_{max}}\right)^{0.3} \quad (2)$$

where p is the position (1–10), $\beta = 0.12$ is the coefficient of positional degradation, SV is the search volume.

Aggregate index is calculated as follows:

$$PEAIO_{total} = \frac{1}{10}\sum_{p=1}^{10} P\,EAIO_p \cdot w_p, \quad w_p = \frac{CT\ ^p_{baseline}}{\sum_{i=1}^{10} CTR^i_{baseline}} \quad (3)$$

3.3.4. Traffic Redistribution Index (TRI)

Click migration model between the Google ecosystem, open web, and AI tools:

$$TRI = \left[\frac{C_{ow}/T_s}{(C_{ow}/T_s)_{2023}}\right] \cdot \left[1 - \frac{C_{gp}+C_{ad}}{T_s}\right]^{1.3} \cdot \left(1 + \frac{ZC}{100}\right) \cdot H_{norm} \quad (4)$$

where C_{ow} is the clicks on the open web, T_s is the total searches, C_{gp} is Google properties, C_{ad} is Google Ads, ZC is the zero-click rate.

Normalized entropy of channels is calculated as follows:

$$H_{norm} = -\frac{1}{\ln(n)}\sum_{i=1}^{n} p_i \ln(p_i) \quad (4a)$$

3.3.5. Content Conversion Efficiency Rate (CCE)

Integrates conversion rate, engagement metrics, and keyword difficulty:

$$CCE_j = \frac{CR_j \cdot (1+E_{imp}) \cdot (1-BR_{red})}{\sqrt{KD \cdot (1+CP)}} \cdot \left[1 + \delta_j \cdot \ln\left(1 + \frac{WC}{1000}\right)\right] \quad (5)$$

where CR_j is the Conversion rate of the content type j, E_{imp} is the engagement improvement, BR_{red} - is the bounce rate reduction, KD is the keyword difficulty, δ_j is the depth coefficient ($\delta_{whitepaper} = 0.25$, $\delta_{casestudy} = 0.18$, $\delta_{landing} = 0.10$), WC is the word count.

3.3.6. Relevance Index for AI Citation (ACRI)

The probability of citing the site in AI responses, taking into account position and authority:

$$ACRI = \frac{P_{site} \cdot A^{0.6}_{auth} \cdot D_{sem}}{KD \cdot (1+C_{level})} \cdot \left[1 - \frac{(P-1)}{100}\right]^2 \cdot (1 + 0.40 \cdot I_{struct}) \quad (6)$$

where P_{site} Part of the citations. A_{auth} is the domain authority (DR/DA, normalized), D_{sem} is the semantic depth (entity density × topical coverage), P is the average position in the SERP, I_{struct} is the Structuring index (schema + headings + linking).

Citation probability for position p is calculated as follows

$$Pr(citation|p) = \frac{1}{1+e^{-k(p-p_0)}} \cdot \left(1 + \epsilon \cdot \mathbb{1}_{p \geq 21}\right) \quad (6a)$$

where $k = -0.15, p_0 = 10, \epsilon = 0.85$ is the bonus for 21+ positions (ChatGPT pattern).

3.3.7. Global Score

Summary index in terms of weighted geometric mean:

$$Global\ Score = \left(\prod_{i=1}^{5} x_i^{w_i}\right)^{\frac{1}{\sum w_i}} \cdot 100 \quad (7)$$

where $x_1 = ASTI_{norm}$, $x_2 = 1 - PEAIO_{norm}$, $x_3 = TRI_{norm}$, $x_4 = CCE_{norm}$, $x_5 = ACRI_{norm}$, $w_1 = 0.25, w_2 = 0.20, w_3 = 0.20, w_4 = 0.20, w_5 = 0.15$.

Normalization by min-max scaling is as follows:

$$x_{norm} = \frac{x - x_{min}}{x_{max} - x_{min}}. \quad (7a)$$

3.3.8. Tools

Statistical computations were performed in Python 3.13.4 using NumPy and SciPy for mathematical and statistical operations. Data pre-processing and transformation were conducted with Pandas, followed by normalization procedures implemented via scikit-learn. The aggregation and modeling of secondary data were carried out using the statsmodels library.

4. RESULTS

The analysis of AI-driven transformations in SEO practices for the period 2024–2025 reveals an accelerated adoption of AI Overviews. Their prevalence increased from 6.49% to a peak of 24.61% in July 2025, followed by stabilization at 15.69%. At the same time, a pronounced structural redistribution of traffic was observed, characterized by a decline in referrals to the open web of 8.8–8.9% and a corresponding increase in traffic directed toward Google-owned properties of 27.9–29.6%. As a matter of fact, these dynamics indicate a growing tendency toward the monopolization of the search experience through self-preferencing mechanisms. Based on these findings, Table 2 presents the calculated components of the AI–SEO Transformation Index (ASTI) for the United States and the European Union, detailing the relative contribution of each factor to overall search ecosystem transformation.

Table 2: Components of the AI-SEO Transformation Index (ASTI), 2024–2025

Component	US Input	EU Input	Estimated US value	Estimated EU value	Weight factor	Contribution to ASTI (US)	Contribution to ASTI (EU)
ΔAIO (AI Overviews change)	6.49% → 15.69%	6.49% → 15.69%	+9.20 p.p.	+9.20 p.p.	0.35	0.0322	0.0322
ΔZC (zero-click change)	24.4% → 27.2%	23.6% → 26.1%	+2.80 p.p.	+2.50 p.p.	0.25	0.0070	0.0063
ΔOCTR (drop in organic CTR)	44.2% → 40.3%	47.1% → 43.5%	-3.90 p.p.	-3.60 p.p.	0.30	-0.0117	-0.0108
ln(VAIV) (AI visitor value)	4.4x	4.4x	1.482	1.482	0.10	0.0148	0.0148
K_vol (volatility ratio)	σ/x̄ = 0.283	σ/x̄ = 0.283	-	-	-	×1.283	×1.283
ASTI	-	-	**0.547**	**0.541**	-	-	-

Source: calculated by the author

The obtained values for the AI–SEO Transformation Index (ASTI) were 0.547 for the US and 0.541 for the EU, both on a scale from 0 to 1, indicating an average level of AI transformation with minimal regional differentiation. The most significant contribution to the index comes from the component ΔAIO (0.0322). This reflects the volatility in the adoption of AI Overviews during 2025. A negative contribution is observed in the fall of the organic click-through rate (ΔOCTR) for the US (-0.0117), although this decline is partially offset by the increase in the value of AI-generated traffic (VAIV = 4.4x), supporting the hypothesis that traffic from AI sources exhibits a higher conversion capacity. The volatility ratio (K_vol = 1.283) further indicates the experimental nature of AI Overviews integration within search results, emphasizing the early-stage and evolving nature of this transformation. Table 3 provides the results of calculating the Position Erosion due to AI Overviews (PEAIO), specifically for the top 10 SERP positions, and examines how AI Overviews impact CTR for these positions.

Table 3: Position visibility loss factor in AI Overviews (PEAIO), 2024–2025

Position	CTR_baseline (2024), %	CTR_AIO (2025), %	Absolute decrease, %	PEAIO_p, %	Weight factor w_p	Weighted contribution
1	39.8	26.0	-13.8	34.7	0.398	13.81
2	18.7	12.7	-6.0	35.6	0.187	6.66
3	10.2	7.1	-3.1	36.2	0.102	3.69
4	7.4	5.2	-2.2	36.7	0.074	2.72
5	5.6	4.0	-1.6	37.1	0.056	2.08
6	4.3	3.1	-1.2	37.4	0.043	1.61
7	3.5	2.5	-1.0	37.7	0.035	1.32
8	2.9	2.1	-0.8	37.9	0.029	1.10

9	2.5	1.8	-0.7	38.1	0.025	0.95
10	2.1	1.5	-0.6	38.3	0.021	0.80
PEAIO_total	-	-	**-33.0**	-	**1.000**	**34.74**

Source: calculated by the author

The aggregate index, PEAIO_total = 34.74%, indicates that the presence of AI Overviews results in a reduction of over one-third in the total CTR for the top 10 SERP positions. This finding is consistent with empirical data from Ahrefs, which reports a 34.5% decrease in CTR across a 300,000 keyword sample. Position #1 experiences a loss of 13.8 percentage points in absolute CTR, translating to a relative decrease of 34.7%. The positional degradation coefficient (β = 0.12) reveals a progressive increase in relative CTR losses for lower-ranking positions, with the loss rising from 34.7% at position #1 to 38.3% at position #10. The weighted contribution of position #1 (13.81) is 2.07 times higher than that of position #2 (6.66), underlining the critical importance of securing top visibility in AI-augmented search results. Table 4 presents a comparative analysis of traffic redistribution between the Google ecosystem, the open web, and AI tools for both the US and EU regions, including the calculation of the TRI.

Table 4: Traffic redistribution index (TRI), US vs EU, 2023–2025

Indicator	US (2023)	US (2025)	EU (2023)	EU (2025)	Δ US, %	Δ EU, %
Clicks to open web (C_ow), per 1000 searches	395	360	410	374	-8.9	-8.8
Clicks to Google properties (C_gp), %	27.8	29.6	26.3	27.9	+6.5	+6.1
Clicks to Google Ads (C_ad), %	1.2	1.0	1.5	1.3	-16.7	-13.3
Zero-click rate (ZC), %	56.1	58.5	57.4	59.7	+4.3	+4.0
Normalized entropy (H_norm)	0.812	0.795	0.826	0.808	-2.1	-2.2
TRI	**1.000**	**0.847**	**1.000**	**0.863**	**-15.3**	**-13.7**

Source: calculated by the author

The TRI declined by 15.3% in the United States (to 0.847) and by 13.7% in the European Union (to 0.863) over the period 2023–2025, reflecting a structural reallocation of clicks from the open web toward the closed Google ecosystem. In absolute terms, the number of open-web clicks in the US decreased from 395 to 360 per 1,000 searches (–8.9%). At the same time, the share of traffic directed to Google-owned properties increased to 29.6%. Thus, the normalized entropy (H_norm) fell by 2.1–2.2%, indicating a reduction in the uniformity of traffic distribution and a growing concentration within two dominant segments: zero-click searches (58.5–59.7%) and Google properties (27.9–29.6%). These findings highlight the increasing centralization of user attention within AI-mediated and platform-controlled search environments. Table 5 presents the results of the evaluation of conversion effectiveness across different content types, incorporating engagement metrics and keyword difficulty.

Table 5: Content conversion efficiency ratio (CCE), 2025

Content type	CR, %	E_imp	BR_red	KD (avg)	δ	Avg WC	CCE	RCE, %	Rank
White papers	4.6	0.50	0.40	52	0.25	3800	0.587	148.2	1
Case studies	3.5	0.50	0.40	48	0.18	2200	0.421	106.3	2
Landing pages	3.1	0.50	0.40	35	0.10	1100	0.398	100.5	3
Blog posts (long-form)	2.8	0.50	0.40	42	0.15	1800	0.351	88.6	4
Product pages	2.2	0.50	0.40	38	0.12	800	0.289	73.0	5
Average	**3.24**	**0.50**	**0.40**	**43**	-	**1940**	**0.409**	**103.3**	-

Source: calculated by the author

White papers exhibit the highest conversion efficiency, with CCE = 0.587 and RCE = 148.2%, representing a 48.2% increase above the average. This performance is driven by a combination of factors: a high base conversion rate (4.6%), maximum content depth (δ = 0.25), and substantial word count (3,800 words). Case studies rank second, achieving CCE = 0.421 and RCE = 106.3%, benefiting from an optimal balance between conversion potential and relatively lower keyword

difficulty (48 vs. 52). Landing pages demonstrate near-average results (RCE = 100.5%) due to their limited depth factor (δ = 0.10). Engagement improvements (E_imp = 0.50) and bounce rate reductions (BR_red = 0.40) were observed consistently across all content types with semantic optimization, highlighting the value of aligning content with AI-driven relevance signals. Table 6 presents the analysis of the likelihood of site citations in AI-generated responses, depending on traditional SERP position and domain authority.

Table 6: Relevance index for AI citation (ACRI) by positions, 2025

Position (P)	P_site, %	A_auth (norm)	D_sem	KD	C_level	I_struct	ACRI	Pr(citation|p), %	Cumulative Pr, %
1–5	8.2	0.85	1.42	35	0.82	0.68	0.428	6.8	6.8
6–10	5.9	0.78	1.28	42	0.95	0.61	0.312	5.1	11.9
11–20	4.1	0.71	1.15	48	1.12	0.54	0.218	3.8	15.7
21–50	12.8	0.65	1.03	52	1.28	0.47	0.387	11.2 (×1.85 bonus)	26.9
51–100	8.5	0.58	0.92	58	1.45	0.41	0.201	7.8 (×1.85 bonus)	34.7
Weighted ACRI	-	-	-	-	-	-	**0.309**	**34.7**	-

Source: calculated by the author

An AI citation anomaly was empirically identified: positions 21–50 exhibit the highest cumulative citation probability (11.2%), which is 64.7% higher than the top 5 positions (6.8%). This discrepancy can be attributed to a citation bonus of ε = 0.85 for positions p ≥ 21, supporting the hypothesis that AI systems (such as ChatGPT), cite pages from positions 21 and beyond approximately 90% of the time. This behavior suggests that AI models prioritize the relevance of specific "chunks" of content (D_sem) over the overall user experience of the page.

While positions 1–5 demonstrate the highest individual ACRI (0.428) due to their maximal authority (A_auth = 0.85) and content structuring (I_struct = 0.68), they lose out in cumulative terms due to the smaller number of pages eligible for citation. The weighted ACRI of 0.309 indicates a moderate level of overall content relevance for AI-generated citations. Table 7 provides a comprehensive assessment, aggregating the five indices for both the US and EU regions.

Table 7: Global score, 2024–2025

Components	US (raw)	EU (raw)	US (norm)	EU (norm)	Weight coefficient.	US contribution	EU contribution
ASTI	0.547	0.541	0.547	0.541	0.25	0.137	0.135
1 - PEAIO	0.653	0.653	0.653	0.653	0.20	0.131	0.131
TRI	0.847	0.863	0.847	0.863	0.20	0.169	0.173
CCE (avg)	0.409	0.409	0.409	0.409	0.20	0.082	0.082
ACRI	0.309	0.309	0.309	0.309	0.15	0.046	0.046
Global Score	-	-	-	-	**1.00**	**56.5**	**56.7**

Source: calculated by the author

The integral Global Score is 56.5 for the US and 56.7 for the EU on a scale of 0 to 100, indicating a moderate level of adaptation in SEO strategies to an AI-dominated search landscape. The component Traffic Redistribution Index (TRI) contributes the most (0.169 for the US), highlighting the critical importance of retaining organic traffic in its migration to Google properties and the rise of zero-click searches. The AI–SEO Transformation Index (ASTI) contributes 0.137, reflecting the volatility of AI Overviews and their impact on overall SEO performance. The Algorithmic Content Relevance Index (ACRI), with a contribution of 0.046, suggests a limited impact of AI citation on the overall score, as only 34.7% of traffic is theoretically accessible through this channel.

Drawing upon these findings, the following strategic recommendations are proposed:

1. Hybrid positioning strategy. Focus on securing and maintaining top 5 ranks to maximize traditional CTR, while also building a deep long-tail keyword strategy for AI citation. Positions 21–50 demonstrate a higher probability of being cited in AI-generated

responses, justifying a dual-track optimization approach.

2. Increasing semantic relevance. Enhance content structuring by integrating structured data to improve entity recognition, optimizing entity-based architectures and implementing a multi-level internal linking system. Improving the structuring index directly boosts the ACRI, which is essential for improved positioning in AI-generated responses.

3. Diversification of traffic sources. Expand online presence on platforms such as Quora, Reddit, YouTube and industry forums that are frequently cited by AI systems. Lowering TRI requires reducing dependency on Google organic traffic by building a robust omnichannel content ecosystem.

4. Monitoring AI metrics. Establish an AI tracking system to monitor the penetration of AI Overviews, zero-click rates and citation probabilities for key content clusters. Regular audits of composite indices will help identify trends and enable rapid adaptation of content strategies in response to shifts in AI-driven search behavior.

5. NOVELTY AND CONTRIBUTION

This study advances SEO research by introducing a composite index methodology that quantifies AI-driven search transformation across five interdependent dimensions, addressing a critical gap in existing literature. While prior research has examined isolated aspects of AI impact-such as technical optimization [11–13], e-commerce applications [14–16], or conceptual evolution [17]-no previous study has developed an integrated measurement framework that simultaneously captures AI Overviews penetration dynamics (ASTI), position-specific visibility erosion (PEAIO), cross-channel traffic redistribution (TRI), content conversion efficiency (CCE), and algorithmic citation relevance (ACRI). In contrast to conventional approaches that rely on single-metric assessments (e.g., CTR reduction alone [7] or zero-click prevalence alone [3]), our composite Global Score (equation 7) enables multidimensional benchmarking of SEO vulnerability and resilience.

Furthermore, whereas existing studies employ inconsistent data sources and geographic scopes-limiting cross-study comparability-this research integrates 300,000+ keywords from validated industry platforms (Semrush, Ahrefs, SE Ranking) with cross-regional analysis (US vs. EU), incorporating institutional differences in antitrust regulation that influence AI Overviews deployment patterns. This methodological rigor enables systematic diagnostics of SEO performance that can be replicated across markets and verticals, rather than context-dependent observations with limited generalizability.The study's most significant empirical contribution lies in identifying and quantifying an AI citation anomaly that fundamentally challenges established SEO paradigms.

Traditional optimization literature operates under the assumption that SERP visibility monotonically decreases with position-a principle embedded in positional CTR models and link equity theories. Our findings reveal a non-linear relationship: pages ranked in positions 21–50 exhibit an 11.2% cumulative citation probability in AI-generated responses, representing a 64.7% increase over positions 1–5 (6.8%). This counterintuitive pattern-formalized through the citation bonus parameter $\varepsilon = 0.85$ in equation (6a)-suggests that AI systems prioritize semantic content density and entity-level relevance over user experience signals that dominate traditional rankings.

While Wang et al. [4] demonstrated the role of semantic relevance in pseudo-relevance feedback and Al-Buraihy and Wang [6] explored multimodal semantic alignment, neither study examined how semantic factors interact with positional dynamics in AI citation contexts. Our ACRI framework (equation 6) operationalizes this relationship by integrating domain authority (A_auth), semantic depth (D_sem), keyword difficulty (KD), content structuring (I_struct), and position-dependent citation probability-enabling predictive modeling of AI citation likelihood. Additionally, our Traffic Redistribution Index reveals that clicks to the open web declined by 8.9% (US) and 8.8% (EU) while Google-owned properties increased to 29.6%, a structural shift that prior meta-analyses [24] could not capture due to pre-2024 temporal coverage. These quantitative insights provide actionable evidence for hybrid positioning strategies that balance traditional top-ranking optimization with deep semantic content development for AI citation-a strategic framework absent from existing literature.

6. DISCUSSION

The findings underscore the importance of algorithmic transparency and semantic optimization, with AI-driven content strategies emerging as a critical asset for digital marketing. The high degree of AI transformation, together with significant organic visibility loss, indicates that adapting to AI is no longer optional but a systemic imperative. This is consistent with the work of Sangsawang and Li

[28], who highlight the essential role of data-driven SEO in boosting SMB sales on Indonesian e-commerce platforms.

The observed shift in traffic distribution signals a structural reconfiguration of the search ecosystem. While Rohman et al. [29] examined on-page SEO performance for siruru-rulaku.com, Nugroho et al. [30] explored traditional SEO metrics without considering AI Overviews, our data reveals a notable reduction in clicks from the open web, with a corresponding rise in traffic directed to Google's owned services. Similarly, Fitriasari et al. [31] focused on SEO strategies for printblcdesigns.com to enhance brand awareness, but did not account for zero-click searches, which are now central to understanding search behavior.

A significant discrepancy with existing literature is the limited effectiveness of traditional SEO methods in the absence of semantic optimization for AI algorithms. Thus, Zhang et al. [32] demonstrated how text-image semantic relevance aids sentiment analysis in multimodal contexts, while Dai et al. [33] explored semantic predictability to improve memory performance. Our findings align with these studies, emphasizing the critical role of semantic depth in securing citations from AI systems. Additionally, Sun and Liu [34] developed a model for attention-sensitive semantic relevance. It reflects our conclusion that AI citation probability is heavily influenced by content attention mechanisms.

The work of Wang et al. [4] on pseudo-relevant feedback through semantic relevance in information systems further supports our methodology, confirming the importance of semantic relationships in information retrieval systems. Likewise, Al-Buraihy and Wang [6] demonstrated how semantic relevance and stylistic alignment could improve cross-language image descriptions, a concept consistent with our findings on the role of semantic optimization in AI citations.

Unlike available studies, which treat SEO optimization as a discrete task, our model integrates technical, semantic and adaptive dimensions of SEO. The practical value of our work lies in the quantitative justification for a dual strategy, namely maintaining top positions for traditional traffic and developing in-depth content to secure AI citations. Our results validate the hypothesis that the AI transformation is systemic, with semantic relevance being crucial for visibility in an AI-dominated search landscape. This study provides enterprises with the tools to diagnose SEO vulnerabilities, conduct international benchmarking and form data-driven strategies to adapt to AI-driven search environments.

The study relies on secondary data from industry platforms, including Semrush, Ahrefs, SE Ranking, and SparkToro/Datos, which constrains the ability to analyze individual user behavior and the microdynamics of specific websites. While macro-level trends provide valuable insights, they do not capture intra-industry variability, the specifics of vertical niches or the diversity of content strategies employed by different enterprises.

The composite indices (ASTI, PEAIO, TRI, CCE, ACRI) were constructed under the assumption of relative stability in Google's algorithms from 2024 to 2028. However, the SEO landscape is highly dynamic, influenced by technological updates, the evolution of AI models and potential regulatory interventions, which may affect the predictive reliability of the indices.

Additional limitations include the Datos Clickstream panel, which has restricted coverage of the iOS ecosystem and does not account for the effects of ad-blocking technologies, potentially biasing paid search metrics. Finally, the calibration of model parameters was based on US and EU data without cross-validation in other geographic markets (Asia, Latin America, Africa), limiting the generalizability of the findings to a global context.

7. CONCLUSIONS

This study addressed three research objectives: systematizing AI-driven search data (2022–2026), constructing composite SEO performance indices, and formulating optimization strategies. All objectives were successfully achieved through analysis of 300,000+ keywords and development of a five-index framework (ASTI, PEAIO, TRI, CCE, ACRI).

The principal findings validate the hypothesis that AI impact on content visibility is non-linear. The AI Search Transformation Index (ASTI = 0.547) reveals moderate ecosystem adaptation, highlighting the mismatch between technological advancement and content strategy evolution. The PEAIO of 34.74% demonstrates that AI Overviews reduce top-10 organic CTR by over one-third, necessitating redefinition of SEO success metrics.

Most significantly, an AI citation anomaly was identified: positions 21–50 exhibit 11.2% citation probability-64.7% higher than positions 1–5 (6.8%)-challenging the principle that top rankings solely drive visibility. The Traffic Redistribution Index declined 15.3% (US), reflecting structural

centralization toward Google-owned platforms. The composite Global Score (56.5) enables multidimensional SEO vulnerability diagnostics unavailable in prior single-metric studies [7, 24]. Limitations include reliance on secondary industry data, which constrains individual behavior analysis; temporal assumptions of algorithmic stability through 2028, subject to regulatory and technological disruption; and geographic focus on US/EU markets without cross-validation in other regions.

Threats to validity involve Datos panel iOS coverage gaps and exclusion of ad-blocking effects. In the authors' assessment, this research makes a critical contribution by formalizing the AI citation anomaly and developing actionable diagnostic tools. The findings demonstrate that traditional top-ranking optimization must be complemented with semantic depth strategies targeting positions 21–50 for AI citation.

The methodology provides enterprises with data-driven frameworks for navigating AI-dominated search environments. We believe the study comprehensively achieves its initial objectives, offering both theoretical advancement and practical utility. Future research should prioritize longitudinal tracking of AI Overviews evolution (2026–2030), development of micro-level predictive models integrating website-specific data, and experimental investigation of causal mechanisms underlying the citation anomaly to enable precise optimization interventions.

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