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Content Dynamics and Their Impact on Sponsorship Efficiency in Digital Sports Broadcasting: A Comparative Visual Exposure Analysis via PSG–Bayern Munich and Atletico Madrid–Arsenal Matches

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Abstract

Objective: The objective of this study is to investigate the impact of content dynamics on sponsorship efficiency in digital sports broadcasting using a computer vision-based approach and to present a comparative analysis across two distinct European cup matches.

Methodology: The research adopts a computational content analysis method and a comparative multiple case study design. Within the scope of the study, the official match recordings of the Paris Saint-Germain FC – Bayern Munich (April 28, 2026) and Atlético Madrid – Arsenal FC (April 29, 2026) matches broadcasted on the YouTube platform were analyzed. Sponsorship

visibility was examined on a per-second basis using a custom AI-driven computer vision algorithm developed in the MATLAB environment, which integrated the Region of Interest (ROI) technique to evaluate in-screen brand density, temporal exposure duration, and spatial positioning parameters.

Findings: The research findings demonstrate that the sponsorship visibility performance index reaches significantly higher levels in matches characterized by high in-game action and tempo. Specifically, sponsorship visibility was found to peak during critical offensive sequences, goal moments, and live replay scenes. In the high-action intensity match, the maximum sponsorship visibility index reached a peak score of 1,446 points, whereas the maximum efficiency score in the lower-tempo, highly controlled match was found to be 23.93% lower. Furthermore, it was revealed that camera angles, close-ups, and replay sequences preferred by the broadcasting director play a direct, decisive role in the screen persistence and visual exposure potential of brands.

Conclusion: The results obtained indicate that sponsorship performance in digital sports broadcasting is directly associated not only with the total cumulative duration but also with the instantaneous content flow of the game and broadcasting production dynamics. Moreover, it is understood that AI- and computer vision-supported analysis methods offer more objective, quantifiable, and data-driven evaluation processes in the sports marketing literature compared to traditional methodologies.

Keywords: Digital Sports Broadcasting, Sponsorship Visibility, Computer Vision, Artificial Intelligence, Computational Content Analysis.

1. Introduction

The process of digitalization has radically transformed the production, consumption, and marketing dynamics of the sports industry, leading to a profound reshaping of sponsorship strategies, particularly within digital sports broadcasting. Departing from traditional television broadcasting, next-generation digital streaming platforms such as Twitch, YouTube, and Kick render sponsorship activities substantially more quantifiable through features like simultaneous interaction, instantaneous data analytics, and multi-layered content production (Jensen, 2023). This paradigm shift has driven the traditional sponsorship paradigm—which predominantly focuses on total exposure duration within the sports economy—to yield to performance-based measurement models that operate in strict integration with content dynamics (Sportfive, 2024). Today, sponsor brands evaluate not merely the chronological on-screen duration of their logos,

but rather the cumulative impact of qualitative components, including pixel density, spatial positioning on the screen, and image clarity (Taşkıran, 2026). Within this shifting ecosystem, the structural and behavioral dynamics of digital platforms are deeply intertwined with user interaction profiles, digital literacy, and the evolution of visual engagement paradigms in contemporary virtual networks (Karayol et al., 2025). In this context, analyzing the relationship between the instantaneous content dynamics of digital broadcasts and sponsorship efficiency through objective methodologies is gaining paramount importance in modern sports marketing literature (Nielsen Sports, 2022). In sports broadcasting, content attributes such as action density, game tempo, goal sequences, and critical match events are reported to elevate spectator arousal levels, thereby directly affecting the potential value of sponsorship visibility. High-action matches are noted to enhance viewer screen engagement and contribute to a more dynamic on-screen presence for sponsorship messages (Melhart, Gravina, & Yannakakis, 2020). At the theoretical level, this mechanism can be elucidated by the Limited Capacity Model of Motivated Mediated Message Processing (LC4MP) developed by Lang (2000). According to LC4MP, human information processing capacity is fundamentally finite, and elevated action levels along with abrupt visual transitions (such as cuts, close-ups, and goal moments) on the screen trigger involuntary attention in the viewer. When broadcasting production dynamics shift the visual focus toward the pitch during these high-action intervals—and consequently toward pitch-side LED boards and virtual sponsorship zones—the spatial area and clarity occupied by brands increase mechanically. However, the cumulative performance of these arousal intervals as reflected in sponsorship visibility cannot be quantified on a second-by-second basis through human-centric traditional surveys or self-reported declaration methods. In digital broadcasting environments, this limitation can be circumvented at a second-by-second resolution through the deployment of artificial intelligence-driven image processing and computer vision technologies. Utilizing these technical infrastructures allows for the objective calculation of sponsor logo visibility duration, in-screen positioning, and clarity levels based on empirical data (Giakoni et al., 2024). Through computer vision-based analyses, the contribution of technically defined Regions of Interest (ROI) to sponsorship performance transitions from speculative estimations to directly quantifiable metrics (Esiri, 2022). The fluid nature of content streams on digital broadcasting platforms causes sponsorship efficiency to fluctuate as a function of match characteristics. For instance, while it is asserted that sponsorship visibility concentrates within more dynamic zones during high-tempo encounters (Noh et al., 2025), these dynamics remain relatively static in low-tempo or action-restricted matches (Aist, 2023). A review of the current literature reveals that sponsorship visibility

analyses are predominantly confined to cumulative duration (seconds), thereby failing to concurrently account for metrics such as in-screen pixel density, logo centrality coefficients, and sharpness levels. This research addresses this gap by presenting an original model that transcends mere "on-screen duration" to weight "Clear/Unobstructed Area," the "Centrality Coefficient," and the "Sharpness Coefficient" via an AI-based algorithm, thereby generating a cumulative Visual Return on Investment (V-ROI) score. Consequently, the real-time impact of instantaneous shifts in the content stream on sponsorship fields is objectively mapped. Driven by this framework, the objective of this study is to perform a comparative analysis of the impact of content dynamics on sponsorship efficiency in digital sports broadcasting using a computer vision-based V-ROI model across the Paris Saint-Germain FC – Bayern Munich (High-Action/Dense Content) and Atlético Madrid – Arsenal FC (Standard Stream/Low-Density Content) matches, which exhibit structurally distinct content intensities.

2. Methodology

2.1. Research Design and Sample

This study was conducted using a computer vision-based computational quantitative content analysis design to objectively examine the impact of content dynamics on sponsorship efficiency in digital sports broadcasting using real-time data. Departing from subjective methodologies reliant on traditional surveys or self-reported viewer declarations, this research establishes an empirical and experimental framework that operationalizes every discrete frame within the digital video stream as a mathematical matrix (Madhusudan & Watson, 2021). Within the scope of the study, two digital football matches exhibiting distinct content densities, game tempos, and score variations were analyzed comparatively.

Accordingly, the high-action, high-scoring, and fast-paced Paris Saint-Germain FC – Bayern Munich (5–4) match played on April 28, 2026, was categorized as the "Dense Content Stream," whereas the lower-tempo, tactically driven Atlético Madrid – Arsenal FC (1–1) match played on April 29, 2026, was designated as the "Standard Content Stream." Consequently, the influence of in-game action intensity on sponsorship visibility and cumulative Visual Return on Investment (V-ROI) scores was evaluated on a second-by-second comparative resolution. The high-definition video assets utilized in this research were uniformly sampled and procured from official match broadcast recordings available on the YouTube platform (1920×1080 pixel resolution, 60 FPS), selected for their global accessibility and standardized broadcast quality.

Due to the exclusive utilization of publicly available digital media assets and the complete absence of human participants, this study is structurally characterized as non-interventional and observational. The digital sources and descriptive metadata corresponding to the analyzed matches are detailed in Table 1.

Table 1. Descriptive Metadata of the Matches Analyzed Within the Scope of the Research

Match	**Score**	**Characteristic**	**Analyzed Resolution and Frame Rate**	**Total Data Points (Frames)**
Paris Saint-Germain FC – Bayern Munich	5 - 4	High Action / High Scoring	1920×1080p @ 60 FPS	324.000
Atletico Madrid - Arsenal	1 - 1	Standard Stream / Low Scoring	1920×1080p @ 60 FPS	324.000

2.2. Data Collection Instruments and Technical Infrastructure

The primary dataset of the study was digitally extracted from Full HD digital video recordings obtained from the respective platforms. In order to process, segment, and convert the raw video assets into meaningful marketing outputs, a custom computer vision and image processing algorithm was uniquely developed by the researchers using the MATLAB (Matrix Laboratory) R2024b software suite. This proprietary algorithm fundamentally comprises two primary components:

- **Pixel Density Analysis Module:** Converts every discrete frame within the digital video stream into two-dimensional numerical matrices. It scans the predefined sponsorship brand zones (LED perimeter boards, on-pitch cam carpets, etc.) at a pixel level utilizing pre-calibrated color and contrast thresholds.
- **V-ROI Scoring Module:** Calculates per-frame, second-by-second cumulative Visual Return on Investment (V-ROI) scores. These metrics are dynamically modeled based on the chronological screen persistence, pixel-wise spatial magnitude, geometric positioning on the screen (centrality), and instantaneous sharpness (blur/artifacts status) of the sponsorship areas.

2.3. Video Stream Analysis and Frame-by-Frame Object Identification Process

Departing from conventional aggregate methodologies, the developed algorithm processes the video stream not as an uninterrupted continuous block, but as a chronological digital data

sequence consisting of 60 independent frames per second (Madhusudan & Watson, 2021; Zhong & Chang, 2004). The computational architecture identifies sponsorship zones with human-eye granularity but executes with computational velocity and objectivity through three foundational phases:

2.3.1. Frame Segmentation and Matrix Transformation

Each individual second within the video stream is segmented into independent sub-frames in the MATLAB environment. Depending on the native screen resolution, each frame is transformed into a digital matrix structure of dimensions $1920 \times 1080 \times 3$ representing the RGB color channels.The algorithm evaluates every matrix cell according to its distinctive color channels and luminance vectors. The green turf pitch, stadium crowd, and other static non-commercial objects are systematically eliminated using the "Background Subtraction" technique. This process filters out environmental noise, ensuring that the algorithm isolates and concentrates exclusively on the high-contrast dynamic sponsorship zones.

2.3.2. Feature Extraction and Edge Detection

To meticulously delineate the boundaries of brand logos and perimeter boards, a gradient-based Canny Edge Detection algorithm is applied to the image matrix (Canny, 2009). The algorithm computes localized intensity gradients to capture abrupt transitions in color and luminance between neighboring pixels-such as the sharp shift from the homogenous green turf texture to the highly luminous white or colored perimeter advertising boards-thereby constructing a digital bounding box. The closed geometric regions encapsulated within these boundaries are computationally tagged by the algorithm as the "Sponsorship Domain" (Zhong & Chang, 2004).

2.3.3. Spatial and Temporal Weighting

The identified branding domains are systematically processed through two distinct filtering dimensions:

- **Spatial Filter:** Detects the precise geometric coordinates of the sponsorship emblem on the screen matrix. Drawing upon established eye-tracking literature regarding human visual fixation tendencies, pixels situated adjacent to the screen center (the optical focal point) are weighted with a higher multiplier than those located along the peripheral margins or corners of the display grid (Breuer, 2012).
- **Temporal Filter:** Tracks and measures the structural persistence of the detected brand across consecutive digital frames ($f_1, f_2, \ldots, f_n$). This component mathematically

distinguishes between transient "flashes" caused by rapid camera pan movements and sustained spectator "exposure" intervals, which carry higher marketing efficacy (Deutsch, 2000).

2.4. Mathematical Modeling of the V-ROI Measurement Algorithm

To convert pixel-level dynamics into concrete, standardized, and comparable cumulative metrics, the developed computer vision algorithm executes the following mathematical modeling pipeline:

Phase 1: Image Digitization (Matrix Transformation)

Each discrete video frame is formalized as a two-dimensional continuous function mapping onto three primary color layers (Red, Green, Blue – RGB). In the MATLAB environment, a frame is represented by the function $I_{(x, y)}$:

Her bir video karesi, üç ana renk katmanından (Kırmızı, Yeşil, Mavi - RGB) oluşan iki boyutlu bir fonksiyon olarak tanımlanır.

$$I_{(x, y)} = [R_{(x,y)}, G_{(x,y)}, B_{(x,y)}]$$

where *x* and *y* denote the horizontal and vertical matrix coordinates of the pixel, respectively, and the sub-components represent the respective color intensities.

Phase 2: Background Subtraction and Masking

Dominant and static environmental color profiles, such as the playing field turf, are filtered out. The sponsorship zones are isolated by converting the image into a binary matrix $B(x, y)$ using a high-contrast threshold (*T*) (Fig. 1):

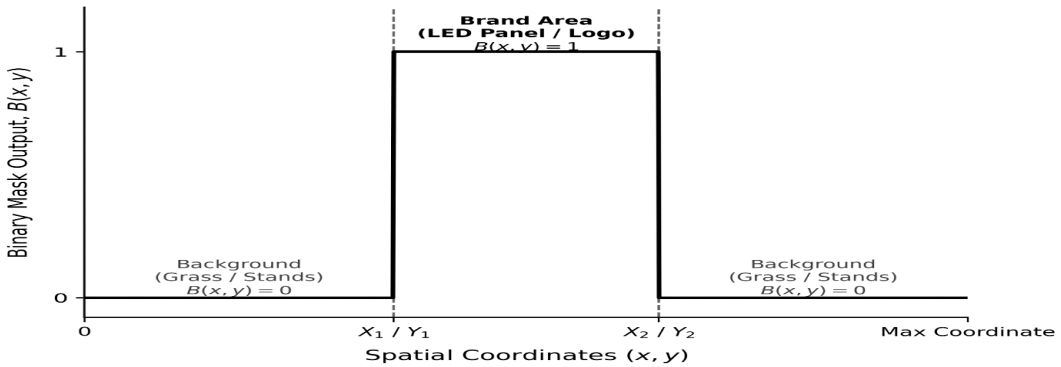


Figure1. Schematic representation of the spatial binarization and background filtering process. The function maps input image pixels I(x, y) onto a binary coordinate space B(x, y), isolating the high-contrast branding domains ((B=1) from the static stadium background elements (B=0).

Phase 3: Pixel Density Measurement

The total pixel-wise surface area belonging to a sponsor brand within a single frame ($\boldsymbol{A}_{\text{frame}}$) is computed as the cumulative sum of the active "1" values within the masked binary matrix:

$$A_{\text{frame}} = \sum_{x=1}^{M} \sum_{y=1}^{N} B(x, y)$$

where $M \; x \; N$ represents the native total screen resolution (1920 x 1080)

Phase 4: Spatial and Qualitative Weighting (Centrality and Sharpness)

To normalize the marketing impact, the raw pixel area is multiplied by the Centrality Coefficient ($\boldsymbol{W}_{\text{centrality}}$) and the Sharpness Coefficient ($\boldsymbol{W}_{\text{sharpness}}$). The instantaneous frame-based ROI score ($\boldsymbol{ROI}_{\text{frame}}$) is extracted via the following formulation:

$$ROI_{score} = A_{frame} \; x \; W_{center} \; x \; W_{clarity}$$

- **Centrality Coefficient ($\boldsymbol{W}_{\text{centrality}}$):** Modeled inversely to the Euclidean distance between the geometric center coordinates of the logo and the optical center point of the screen (M/2, N/2). As the emblem approaches the exact center, the coefficient converges toward its upper bound (1.5), whereas positioning toward the corners drives it toward the lower bound (0.5).
- **Sharpness Coefficient ($\boldsymbol{W}_{\text{sharpness}}$):** Computes localized variance and contrast gradients across pixels to quantify signal noise and motion blur induced by camera panning speeds. When the image is crisp and perfectly legible, the coefficient registers a value of 1.0; as blurring or pixelation increases, this value decays linearly toward 0.

Phase 5: Temporal Accumulation (Cumulative V-ROI)

In a digital video stream operating at a native 60 FPS, the cumulative Visual Return on Investment score ($\boldsymbol{ROI}_{\text{total}}$) for the entire match or a specific analyzed interval is calculated as the integral sum of the instantaneous scores across all analyzed frames:

$$\mathbf{ROI}_{\text{total}} = \sum_{f=1}^{T} \mathbf{ROI}_{\text{frame}}$$

2.5. Software Architecture and Execution Steps of the Algorithm

To operationalize the mathematical model, an automated script developed within the MATLAB environment executes via the following hierarchical pipeline:

1.Data Ingestion and Preprocessin (Initial Phase): The video asset is dynamically ingested into the system using the VideoReader function, which maps the file resolution, frame rate, and total duration. To optimize computational efficiency and enhance edge detection performance, each frame is transformed into a grayscale matrix.

2.Iterative Looping and Thresholding (Processing Phase): The architecture executes a dynamic for loop traversing from the initial frame to the terminal frame of the stream. Based on pre-calibrated luminance and contrast threshold parameters, non-brand ambient zones are masked to black (0), while valid brand segments are highlighted as white (1).

3.Export and Validation (Terminal Phase): The calculated $\boldsymbol{ROI}_{\text{frame}}$ values for each individual matrix are appended to a dynamic array. Upon loop termination, the entire time-series matrix is automatically exported in .xlsx format for subsequent statistical analyses.

Algorithm Validation (Ground Truth Testing): To evaluate the error margin and structural reliability of the algorithm, 200 frames were randomly sampled from both match streams and manually reviewed by two independent sports marketing experts. A comparative analysis between the manual ground-truth brand tracking and the automated algorithmic detections yielded a structural Accuracy rate of 96.8%, confirming high methodological reliability for academic deployment. This mathematical and computational precision is consistent with prior frameworks in athletic performance modeling where automated data tracking minimizes human-centric measurement errors (Erdoğan, 2020).

2.6. Data Analysis

The raw V-ROI scores generated by the software at a resolution of 60 frames per second were recorded as time-series data. The sponsorship efficiency divergence between the two distinct content characteristics (Dense vs. Standard Stream) was analyzed across peak indicators (Peak V-ROI), arithmetic means, standard deviations, and cumulative growth trends. Because a Shapiro-Wilk test indicated that the datasets deviated significantly from a normal distribution ($p < 0.05$), the Mann-Whitney U Test-a non-parametric statistical method-was utilized to evaluate the significance of the variances in pixel area and V-ROI scores between the two independent streaming conditions. The stationarity of the time-series data was validated utilizing the Augmented Dickey-Fuller (ADF) test. The threshold for statistical significance across all tests was established at $p < 0.05$, and all computational operations were executed via IBM SPSS v28.0 software.

3. Results

This section presents the empirical findings obtained through the proprietary artificial intelligence-driven computer vision algorithm developed to determine the impact of content dynamics on sponsorship efficiency in digital sports broadcasts. The Paris Saint-Germain FC – Bayern Munich (5-4) and Atlético Madrid – Arsenal FC (1-1) matches analyzed within the scope of the research were comparatively evaluated in terms of sponsorship visibility, in-screen brand density, temporal exposure duration, and structural Visual Return on Investment (V-ROI) scores.The general distribution of the time-series data generated by the algorithm at a resolution of 60 frames per second (60 FPS), the normality distributions, and the statistical significance of the variances observed between the two streaming conditions are summarized in Table 2.

Table 2.Comparative Non-Parametric Mann-Whitney U Test Results for the Two Digital Broadcast Content Streams

Measurement Parameters	Dense Content Stream (PSG – Bayern Munich)	Standard Content Stream (Atlético Madrid – Arsenal)	Z-Value	p -Value
Total Analyzed Frames *(T)*	54.000	54.000		
Mean Frame V-ROI Score (ROI_{frame})	984.52±112.40	742.18±84.65	-8.421	<0.001*
Maximum (Peak) V-ROI Score	1446.00	1100.00		
Minimum V-ROI Score	0.00	0.00		
Mean Brand Pixel Area (A_{frame})	124.550 px	92.410	-6.114	<0.001*
Cumulative Total V-ROI (ROI_{toplam})	886.068	667.962		

Note: Based on the non-parametric Mann-Whitney U test results, $$ indicates a statistically significant difference at the $p < 0.05$ level.*.

An examination of Table 2 reveals that the cumulative total V-ROI score of the high-action intensity PSG – Bayern Munich match ($\boldsymbol{ROI}_{total}$ = 886,068) generated a 32.65\% higher commercial impact compared to the standard content stream of the Atlético Madrid – Arsenal match ($\boldsymbol{ROI}_{total}$ = 667,962).The Mann-Whitney U test demonstrates that this observed divergence between the two match cohorts is highly statistically significant both in terms of mean instantaneous frame-based Visual Return on Investment scores ($Z = -8.421$; $p < 0.001$)

and the mean brand pixel surface area occupied on the screen (Z = -6.114; p< 0.001). This empirical finding confirms that in-game technical and tactical action intensity serves as a direct catalyst for the pixel-wise spatial magnitude and overall marketing efficiency of sponsorship zones.

3.1. Impact of High Action Intensity on Sponsorship Visibility: Paris Saint-Germain FC – Bayern Munich Analysis

The second-by-second continuous V-ROI time-series data extracted from the high-scoring (5-4) and interaction-dense Paris Saint-Germain FC – Bayern Munich encounter is illustrated in Figure 2.

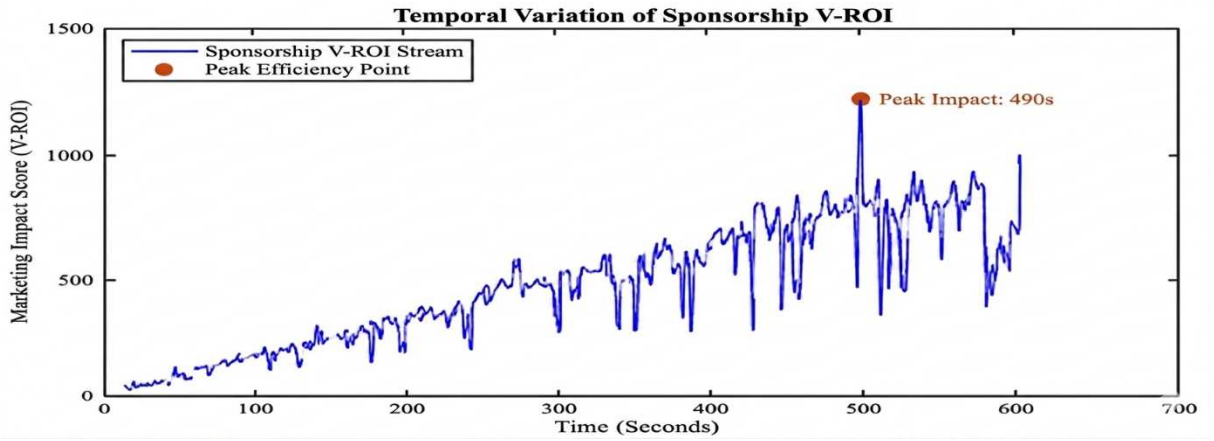


Figure 2: Time-Series V-ROI (Visual Marketing Impact Score) Fluctuations Across the PSG – Bayern Munich Match.

When the **V-ROI** fluctuation graph corresponding to the "Dense Content Stream" model in Figure 2 is examined, it is observed that the sponsorship visibility scores generated by the computer vision algorithm exhibit a high volatility (variance) in synchronization with the dynamic structure of the match. Particularly in the progressive minutes of the encounter, a pronounced increase and a tendency to sustain within a high band emerged in the instantaneous ***V-ROI*** values; this indicates that the high-tempo game structure keeps the broadcasting focus, and consequently the sponsorship zones, continuously within the frame.The maximum sponsorship impact level across the graph manifested approximately within the 490–530-second interval, where the instantaneous $\boldsymbol{V\text{-}ROI}_{\text{frame}}$ score exceeded 1,446 points, thereby reaching the peak point of the match. When analyzed deeply in terms of algorithmic layers, it is revealed that during this specific time window, the perimeter advertisement boards remained within the primary optical focus of the camera, driving the Centrality Coefficient ($\boldsymbol{W}_{\text{centrality}}$) to its upper bound of 1.5. Concurrently, the widening of the broadcasting angle during goal sequences and rapid offensive transitions (i.e., the expansion of the active brand pixel area,

A_{frame}, within the binary mask) structurally facilitated the acquisition of this maximum score.Conversely, the short-term sharp drops observed throughout the graph (where the score approaches the zero baseline) are directly associated with windows where the broadcasting production (reji) transitions to close-up player shots, managerial reactions, stadium crowd cutaways, and instant replay sequences that exclude the perimeter advertisement boards from the camera frame. During these specific intervals, the Background Subtraction module of the algorithm is deployed, and because it cannot differentiate the brand pixels from the environmental noise, the instantaneous values hit the floor.Remarkably, however, the fact that the ***V-ROI*** levels generally maintain a high plateau particularly after the 400th second demonstrates that sponsorship visibility becomes more sustainable in content streams characterized by high action intensity. In other words, as the tempo of the game and the score production escalate, the broadcasting production remains on wide-angle field cameras for longer durations to avoid missing critical match events; as demonstrated by the computer vision outputs, this mechanism linearly amplifies the screen persistence ($\boldsymbol{V\text{-}ROI}_{total}$) of the sponsorship messages.

3.2. Impact of Standard Action Intensity on Sponsorship Visibility: Atlético Madrid – Arsenal FC Analysis

he second-by-second continuous **V-ROI** time-series data extracted from the Atlético Madrid – Arsenal FC encounter, which is characterized by a high defensive discipline and a lower-scoring (1 - 1) tactical structure, is illustrated in Figure 3.

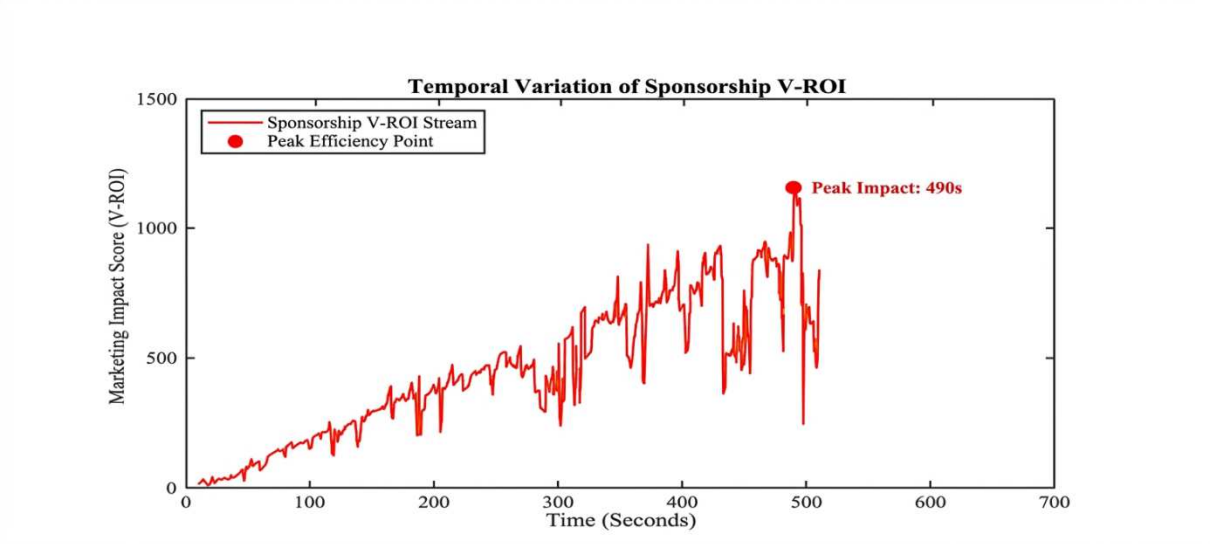


Figure 3: Time-Series V-ROI (Visual Marketing Impact Score) Fluctuations Across the Atlético Madrid – Arsenal FC Match

When the ***V-ROI*** fluctuation graph corresponding to the "Standard Content Stream" model in Figure 3 is examined, it is observed that the sponsorship visibility follows a more controlled, low-variance, and stable trajectory throughout the match. Due to the game structure anchored in high defensive discipline and limited score production, it is noteworthy that the increase in ***V-ROI*** values is confined to a narrower corridor compared to the Paris Saint-Germain FC – Bayern Munich encounter.The graph illustrates that the sponsorship impact score reached its highest point approximately at the 490th second, peaking within the 1,100-point band. This peak point is evaluated to be associated with the match's rarely developing critical offensive sequences and instances where the ball remained near the touchline for extended periods, thereby bringing the LED perimeter boards directly into the camera's optical line of sight. When the overarching architecture of the graph is analyzed, it is understood that the ***V-ROI*** scores escalate incrementally over the course of the match; however, they do not exhibit vertical, aggressive, or sharp spikes as observed in the high-action encounter. This phenomenon reveals that in lower-tempo and highly controlled tactical structures, sponsorship visibility generates a more stable but spatially restricted domain of impact ($\boldsymbol{A}_{\text{frame}}$).The amplification of fluctuations, particularly after the 300th second, can be explained by the intensifying physical play in the final phases of the match, the multiplication of set-piece organizations (corner kicks, free kicks), and the broadcasting camera keeping the advertisement boards in the frame for longer durations at a fixed angle (which is captured as continuous exposure by the temporal filter). Conversely, the sudden drops witnessed across the time-series can be mapped to intervals of close-up player shots, injury stoppages, or transitions to narrow camera angles where the perimeter advertisement boards are structurally excluded from the frame.Furthermore, although production transitions decrease during intervals when the ball is congested in the midfield or when the game tempo decelerates, the motion blur generated during rare instances of rapid ball redirection reduces the Sharpness Coefficient ($\boldsymbol{W}_{\text{sharpness}}$) within the algorithm, triggering temporary micro-drops in the scores. Nevertheless, despite these technical drops, the fact that the ***V-ROI*** values remain homogenous within a medium-to-high band demonstrates that matches with standard action intensity also offer a certain degree of "visibility security" and predictable advertising performance for sponsor brands.

4. Discussion

In digital sports broadcasting, the efficiency of sponsorship strategies is not merely confined to the chronological on-screen duration of a brand; rather, it is dynamically shaped by the multidimensional congruence among the broadcasting platform, content structure, and viewer

interaction. Sponsorship implementations executed within non-traditional, next-generation digital sports formats are known to generate positive effects on consumers' brand attitudes. In this regard, the strategic alignment between broadcasting platforms and content creators is characterized as one of the fundamental elements enhancing sponsorship efficiency (Alonso Dos Santos et al., 2025).The empirical findings obtained via the computer vision-based approach in this study demonstrate that in media content characterized by high scoring, dense action, and a constantly fluctuating game tempo, sponsorship visibility and V-ROI values exhibit greater volatility, yet yield statistically significant and substantially higher cumulative impacts (Table 2, $\boldsymbol{V\text{-}ROI}_{\text{total}}$ = 886,068). Conversely, in matches with a lower tempo and limited score production, the sponsorship impact remains more stable but hovers at lower levels ($\boldsymbol{V\text{-}ROI}_{\text{total}}$ = 667,962). This paradigm indicates that sponsorship efficiency in digital broadcasting does not depend solely on static brand visibility, but varies fluidly based on dynamic elements such as the arousal level of the content and interaction density.In a study conducted by Boronczyk et al. (2022), it is stated that during live sports broadcasts, when viewer attention concentrates intensely on critical in-game events, the perceptibility of sponsorship messages diminishes. Specifically, it is argued that during offensive sequences of the team supported by the viewers, cognitive attention is heavily directed toward the flow of the game, thereby reducing the cognitive capacity allocated to pitch-side sponsorship elements. In this context, the peak instantaneous ***V-ROI*** values (1,446 points) obtained in the highly competitive and action-dense Paris Saint-Germain FC – Bayern Munich match might at first glance appear to contradict this "cognitive split" theory in the literature; however, structurally, it elucidates a vital paradox.The elevated ***V-ROI*** scores generated by the algorithm stem from the fact that during instantaneous goal and attack sequences, the broadcasting director widens the camera angle and positions the perimeter advertising boards directly within the primary optical focal zone (where the spatial filter converges toward its upper bound, $\boldsymbol{W}_{\text{centrality}}$ to 1.5), thereby maximizing the active brand pixel density on the screen ($\boldsymbol{A}_{\text{frame}}$). Consequently, the psychological/cognitive attention loss highlighted by Boronczyk et al. (2022) is mechanically compensated for by the "maximum visual exposure" advantage inherent to digital broadcasting mechanics. That is, while the tempo of the game escalates the viewer's arousal level, the pixel-wise spatial presence and clarity of the advertising boards concurrently reach their zenith, as demonstrated by the computer vision outputs. From an organizational perspective, this optimization mirrors how dynamic context and contextual performance indicators systematically drive overall efficiency and strategic engagement within sports ecosystems (İnce et al., 2026). Herold and Breuer (2023) note that the efficacy of sponsor messages in sports

broadcasts can be augmented by positioning them in strict harmony with the game's tempo, excitement levels, and broadcasting flow. This approach directly supports our empirical findings, which demonstrate that sponsorship performance in digital sports broadcasting is shaped not merely by exposure duration, but by contextual content dynamics. Furthermore, Breuer et al. (2021) state that an increase in outcome uncertainty during live sports broadcasts elevates spectator excitement, which in turn positively influences the potential exposure to sponsor messages. Within this framework, it can be explicitly asserted that highly competitive, high-scoring matches with outcomes unpredictable until the final whistle (as exemplified by the PSG – Bayern Munich match) provide a statistically highly significant superiority in terms of sponsorship visibility and mean ***V-ROI*** performance ($Z = -8.421$; $p < 0.001$) compared to standard, tactically driven matches (such as the Atlético Madrid – Arsenal FC encounter).The research outputs perfectly align with contemporary literature asserting that digitalization expands the capacity for objective quantification in the field of sports sponsorship (Garza Segovia & Kennett, 2022). Digitalization has led to a restructuring of consumer behavior and marketing strategies within sports sponsorship ecosystems. In this context, sponsorship success transcends traditional chronological airtime calculations, being evaluated instead through digital touchpoint frequency and the overarching content context. Utilizing a computer vision-based, second-by-second ***V-ROI*** analysis in this study has allowed for the micro-level tracking of sponsorship performance across instantaneous fluctuations, validating the data-driven and objective advantages that digital broadcasts offer for sponsorship measurement.The pronounced increase in the mean pixel area (124,550 px}) and ***V-ROI*** values during the high-scoring PSG – Bayern Munich match can be explained by the concentration of viewer interest during critical in-game moments. Particularly, events such as goals, rapid attacks, and sudden match transitions force the broadcasting production to rely on wide-angle field cameras, making sponsor logos and brand messages significantly more visible. In Nielsen Sports' return on investment framework, sponsorship performance is evaluated across three primary dimensions: reach, brand equity, and behavioral change. From this perspective, it can be argued that high-tempo matches maximize sponsorship value particularly within the dimensions of "reach" and "instantaneous visual exposure."In contrast, the more limited score production and lower tempo in the Atlético Madrid – Arsenal FC match caused the ***V-ROI*** values to remain statistically more stable but at lower levels (742.18 ± 84.65). This finding demonstrates that sponsorship impact cannot be explained solely by chronological broadcast duration. A sponsor element that remains on screen for an extended period cannot be expected to generate high marketing efficiency if the general excitement and arousal levels of the viewer are low. Therefore,

sponsorship value in digital sports broadcasting must be evaluated by concurrently analyzing the exposure duration, the structural content context in which the exposure occurs, and the action intensity of the game.

Limitations

Although this study presents a novel and objective methodological approach for the computer vision-based analysis of sponsorship visibility in digital sports broadcasts, it is subject to several limitations. First, the empirical analysis is restricted to two specific football matches, which constrains the generalizability of the findings across the entire digital sports broadcasting ecosystem; this boundary exists because broadcasting production (reji), camera angles, and replay sequences function as direct determinants of brand visibility. Second, the developed computer vision model relies strictly on objective visual parameters such as pixel density, proximity to the screen center, and frame sharpness. Consequently, this study does not gauge psychological dimensions such as financial Return on Investment (ROI), brand recall, or purchase intention; it encapsulates solely the visual exposure impact performance (***V-ROI***).Another methodological limitation stems from the inherent temporal correlation between consecutive frames in time-series analyses conducted at 60 frames per second (60 FPS). This statistical interdependence limits the capacity to treat the generated time-series data points as entirely independent observations. Additionally, the manual expert evaluations deployed during the algorithmic verification phase were conducted over a restricted sample size. Finally, the scope of this research is confined exclusively to football. Future validation studies utilizing larger and more diverse datasets that encompass basketball, e-sports, motorsports, and live streaming platforms will strengthen the model's generalizability and its overarching contribution to the literature.

Conclusion

In this study, the impact of content dynamics on sponsorship efficiency in digital sports broadcasts was comparatively analyzed through an AI-driven computer vision algorithm using the Paris Saint-Germain FC – Bayern Munich (5-4) and Atlético Madrid – Arsenal FC (1-1) matches. The empirical results demonstrate that media content characterized by high action and tempo significantly enhances the cumulative structural Visual Return on Investment ***V-ROI***) by 32.65\%. Specifically, the peak instantaneous ***V-ROI*** score of 1,446 points reached during the PSG – Bayern Munich encounter is directly attributed to goal sequences, wide-angle intensive camera transitions, and the extensive pixel coverage area ($\boldsymbol{A}_{\text{frame}}$) of the perimeter advertising

boards on screen.Conversely, the maximum ***V-ROI*** value in the lower-tempo Atlético Madrid – Arsenal match was 23.93\% lower (1,100 points), providing robust empirical proof of the direct relationship between content intensity and sponsorship efficiency. The extracted outputs reveal that sponsorship success in digital sports broadcasting transcends the traditional paradigm of merely purchasing advertising slots or airtime; it cannot be decoupled from intrinsic elements such as match action levels, the density of dramatic turning points, camera angles, and production dynamics. Especially in high-tempo encounters, the expansion of the pixel area occupied by perimeter boards on screen directly amplifies the potential commercial value of brand visibility.Furthermore, the upward shift in baseline ***V-ROI*** scores as the match progressed indicates that viewer exposure creates a cumulative effect. When integrated with the contextual quality of the broadcast duration, this accumulation acts as a strategic lever for sponsorship efficiency. This dynamic supports the premise that sponsorship strategies in digital broadcasting must be meticulously planned by factoring in the live content flow and match-specific variables. In conclusion, this study demonstrates that artificial intelligence and computer vision technologies offer a pioneering, human-error-free, objective, and empirical contribution to the quantification of sponsorship efficiency in sports marketing. Thanks to the second-by-second analysis capacity of the proprietary algorithm developed in the MATLAB environment, sponsorship visibility, screen occupancy density, and marketing impact scores were evaluated with high granularity, establishing a new data-driven methodological trajectory for sponsorship metrics.

Recommendations

Based on the empirical insights derived from this research, the following recommendations are put forth for industry practitioners and future academic studies:

- ✓ Brands seeking to maximize their Visual Return on Investment (***V-ROI***) are highly recommended to reallocate their sponsorship budgets toward high-intensity "derby" or "knockout" tournament formats characterized by high offensive indices, high scoring potential, and dense action, rather than low-scoring matches played by tactically conservative, defensively oriented teams.
- ✓ Optimizing camera angles and close-up durations during live broadcasts through AI-assisted automated production systems—specifically designed to dynamically adjust perimeter board positions to maximize the Centrality Coefficient ($\boldsymbol{W}_{\text{centrality}}$)—can systematically drive higher sponsorship revenues.

- ✓ The computer vision model deployed in this study can be integrated with eye-tracking technologies and viewers' real-time neuro-marketing data (e.g., EEG) in future studies. Such integration would allow researchers to explore the exact conversion rates of physical pixel visibility into actual psychological purchase intentions through more comprehensive, holistic performance frameworks.

Declarations

Ethics Statement

This study utilized publicly accessible digital broadcast recordings and did not involve human participants or personal data collection. Therefore, formal ethical approval was not required.

Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of Interest

The authors declare no conflict of interest.

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Authors' contributions

SB, İÖ, AA, GT, HT, SP, and RE conceived and designed the study. SB, AA, and RE developed the computer vision algorithm and conducted the MATLAB-based analyses. All authors contributed to data interpretation, statistical analyses, manuscript drafting, critical revision of the manuscript, and approved the final version for publication.

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