



Original article. Evolution of performance analysis in football: towards a conceptual model across data, analysis, and interpretation. Vol. 12, no. 4; p. 1-38, August 2026. <https://doi.org/10.55040/51zm5h50>

Evolution of performance analysis in football: towards a conceptual model across data, analysis, and interpretation

Evolución del análisis del rendimiento en fútbol: hacia un modelo conceptual entre datos, análisis e interpretación

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Abstract

This article presents a narrative review with a historical and conceptual approach to the evolution of performance analysis in football, from intuitive observation to the development of advanced data analytics techniques and artificial intelligence. Based on academic literature in Spanish and English, a five-stage periodization is proposed: (1) 1863–1924, predominance of observation and intuition within a context of regulatory institutionalization; (2) 1925–1959, consolidation of tactical analysis and professionalization, with the coach as a strategic figure; (3) 1960–1979, incorporation of audiovisual recording and progression towards more systematic observation, together with limitations arising from incomplete information; (4) 1980–2010, development of video analysis, performance indicators, and physical monitoring; and (5) 2011–present, integration of event and positional data and application of machine learning for modelling and decision support. Beyond this evolution, the study proposes a conceptual model that interprets performance analysis as a process structured across three interdependent levels: descriptive, analytical, and interpretative, whose development has been conditioned by the structural limitations of the game. Football presents properties such as nonlinearity, adaptive interaction between opponents, and dependence on the competitive context, which hinder the identification of stable causal relationships. Consequently, technological progress does not eliminate uncertainty, but rather shifts its boundaries towards the interpretative process. Advanced tools expand analytical capacity, but they do not replace the expert judgement required to translate information into applicable decisions.

Keywords: performance analysis; football; video analysis; GPS; artificial intelligence.

Resumen

Este artículo presenta una revisión narrativa con enfoque histórico y conceptual sobre la evolución del análisis del rendimiento en el fútbol, desde la observación intuitiva hasta el desarrollo de técnicas avanzadas de análisis de datos y la inteligencia artificial. A partir de literatura académica en español e inglés, se propone una periodización en cinco etapas: (1) 1863–1924, predominio de la observación e intuición en un contexto de institucionalización normativa; (2) 1925–1959, consolidación del análisis táctico y de la profesionalización, con el entrenador como figura estratégica; (3) 1960–1979, incorporación del registro audiovisual y avance hacia una observación más sistemática, junto con limitaciones derivadas de la información incompleta; (4) 1980–2010, desarrollo del video análisis, los indicadores de rendimiento y la monitorización física; y (5) 2011–actualidad, integración de datos de eventos y posicionales y aplicación de aprendizaje automático para la modelización y el apoyo a la decisión. Más allá de esta evolución, el estudio propone un modelo conceptual que interpreta el análisis del rendimiento como un proceso estructurado en tres niveles interdependientes: descriptivo, analítico e interpretativo, cuyo desarrollo ha estado condicionado por las limitaciones estructurales del juego. El fútbol presenta propiedades como la no linealidad, la interacción adaptativa entre oponentes y la dependencia del contexto competitivo, que dificultan la identificación de relaciones causales estables. En consecuencia, el avance tecnológico no elimina la incertidumbre, sino que desplaza sus límites hacia el proceso interpretativo. Las herramientas avanzadas amplían la capacidad analítica, pero no sustituyen el juicio experto necesario para traducir la información en decisiones aplicables.

Palabras clave: análisis rendimiento; fútbol; video análisis; GPS; inteligencia artificial.



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Introduction

Performance analysis in football has evolved from forms of intuitive observation based on the practical experience of coaches and players to models supported by artificial intelligence, machine learning, and advanced data analytics. The progressive incorporation of technologies such as video analysis, tracking systems, and large-scale data processing has transformed the capacity to observe, record, and model the game, significantly expanding the volume and complexity of the information available for performance analysis (Sarmiento et al., 2014; Otero-Saborido et al., 2021).

At present, positional data, event data, and artificial intelligence models make it possible to analyse collective behaviours, tactical patterns, spatial control, and dynamic interactions between players and teams (Herold et al., 2019; Moya et al., 2025; Teixeira et al., 2025). This development has reinforced approaches that interpret football as a complex, dynamic, and contextual system in which performance emerges from the continuous interaction between players, opponents, space, and competitive context (Vilar et al., 2013; Duarte et al., 2013; Chassy et al., 2018).

However, the increase in descriptive and analytical capacity does not necessarily imply a complete understanding of the game (Mackenzie & Cushion, 2013). Recent literature shows that performance analysis models continue to face limitations arising from the nonlinear nature of football, the contextual dependence of tactical behaviours, the adaptive interaction between opponents, and the difficulty of establishing stable causal relationships between variables and outcome (Liu et al., 2016; Klemp et al., 2021; Wunderlich et al., 2021). Likewise, methodological heterogeneity, dependence on specific metrics, and the need to contextualize data maintain a central role for expert interpretation in decision-making processes (Mackenzie & Cushion, 2013; Mehta et al., 2024). Along these lines, recent reviews of performance analysis in the main European leagues have indicated that the absence of homogeneous criteria and the difficulty of modelling the tactical singularity of teams continue to limit the practical transfer of the knowledge generated (Aguilar, 2026).

Although the literature has extensively analysed the technological and methodological advances in football performance analysis, fewer studies have sought to



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interpret how these developments modify the epistemological limits of understanding and predicting the game. In this context, the present study poses the following research question: how has performance analysis in football evolved from intuitive observation to artificial intelligence, and what structural limitations persist in understanding and predicting the game?

Based on this question, the study adopts the following interpretative hypothesis: technological development has significantly increased the capacity to describe and model performance, but it can hardly eliminate completely the structural limitations derived from the dynamic, strategic, and contextual nature of football, which limits the possibility of establishing stable and generalizable predictions about performance and competitive outcome.

The objective of this article is to analyse, from a historical and conceptual perspective, the evolution of performance analysis in football and to propose a conceptual framework that interprets this process through three interdependent levels: descriptive, analytical, and interpretative. From this approach, the study argues that technological progress does not eliminate the uncertainty inherent in the game, but progressively shifts its boundaries towards the interpretative plane, where contextualization, decision-making, and expert judgement continue to play a central role.

Methodology

Study design and approach

A conceptual narrative review was conducted on the evolution of performance analysis in football, with a historical, methodological, and technological approach. The objective was not to develop an exhaustive systematic review or to quantify the available evidence, but to integrate heterogeneous academic literature in order to construct a theoretical interpretation of the evolution of performance analysis from intuitive observation to artificial intelligence.

The study adopts an interpretative synthesis perspective aimed at identifying relevant transformations in the way the game is observed, recorded, analysed, and interpreted. From this standpoint, the literature was used not only as a source of empirical evidence, but also as a basis for constructing an analytical periodization and a conceptual



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model of performance analysis structured across three interdependent levels: descriptive, analytical, and interpretative.

Bibliographic search and literature selection

The bibliographic search was carried out in Web of Science, Scopus, PubMed, and SPORTDiscus, with no initial time restrictions, and included publications in Spanish and English. The search was conducted iteratively between January 2024 and April 2026, with successive phases of literature identification, review, and updating, in order to incorporate classic studies, relevant methodological works, and recent publications on technologies applied to football performance analysis.

The search strategy combined a core block on performance analysis with thematic blocks linked to the historical and technological evolution of the field. The main block included terms such as “análisis del rendimiento”, “análisis del juego”, “análisis notacional”, “match analysis”, “performance analysis”, and “notation analysis”, combined with “fútbol”, “football”, or “soccer”.

This block was complemented with terms related to five main domains: tactical evolution and football history; notational analysis and video analysis; physical monitoring through GPS and wearable devices; positional data, tracking, and event data; and artificial intelligence, machine learning, deep learning, and predictive models applied to football.

The selection of literature was guided by criteria of conceptual relevance, historical representativeness, methodological influence, and contribution to the analytical framework of the study. Priority was given to works that helped to understand significant changes in the forms of observation, recording, modelling, and interpretation of performance, as well as studies addressing the structural limitations of analysis in football, including incomplete information, nonlinearity, contextual dependence, and uncertainty in decision-making.

Conceptual organization and analytical framework

The selected literature was organized through an analytical periodization constructed from the main historical, methodological, and technological changes identified in the development of performance analysis in football. This periodization does not respond solely to a chronological division, but to dominant transformations in the nature of analysis: from intuitive and qualitative observation, through audiovisual



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recording and notational coding, to the integration of large-scale data, positional tracking, and artificial intelligence.

Based on this organization, the analysis was structured into five stages: observation and intuition in the context of regulatory institutionalization; development of tactical analysis and professionalization; incorporation of audiovisual recording and progression towards systematic observation; consolidation of video analysis, performance indicators, and physical monitoring; and contemporary integration of event data, positional data, and machine learning models.

As the interpretative axis of the study, these stages were analysed through a conceptual model composed of three interdependent levels. The descriptive level refers to the capture and recording of information about the game; the analytical level, to the processing, classification, and modelling of such information; and the interpretative level, to the translation of data and models into decisions applicable to training, competition, and strategic planning.

Limitations of the methodological approach

The present study has the limitations inherent to a conceptual narrative review. The selection of literature did not follow a closed systematic protocol nor did it include a formal assessment of the methodological quality of all the works reviewed. Therefore, the results should not be interpreted as an exhaustive synthesis of the available evidence, but as a theoretical integration aimed at constructing a conceptual framework on the evolution of performance analysis in football.

Likewise, the proposed periodization involves an interpretative component, and the stages identified should not be understood as closed compartments, but as partially overlapping phases. From this perspective, the development of performance analysis is interpreted not only as an accumulation of technological tools, but also as a progressive displacement of limitations towards the interpretative plane, where uncertainty, competitive context, and expert judgement continue to operate.

Results of the review

Historical periodization and transformations in performance analysis

The evolution of performance analysis in football does not correspond to a strictly linear process, but to a progressive and partially overlapping development of different



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forms of observation, recording, modelling, and interpretation of the game. This evolution has been conditioned by structural transformations that have shaped modern football, including the institutionalization of rules, the professionalization of sport, technological development, commercialization, and the international mobility of players and coaches.

These factors not only modified competitive performance, but also the ways in which it was analysed, affecting the availability of information, the tools for observation and recording, and the interpretative frameworks used by coaches, analysts, and researchers. From this perspective, the evolution of performance analysis can be interpreted as a progressive development of the descriptive, analytical, and interpretative levels proposed in the conceptual framework of the study.

Based on the literature reviewed, a periodization structured into five major stages is proposed: (1) observation and intuition in the context of regulatory institutionalization; (2) development of tactical analysis and professionalization; (3) incorporation of audiovisual recording and progression towards forms of systematic observation; (4) consolidation of video analysis, performance indicators, and physical monitoring; and (5) integration of positional data, Big Data, and artificial intelligence applied to performance analysis.

Figure 1 synthesizes this evolution through a timeline representing the main historical and methodological transformations in football performance analysis.

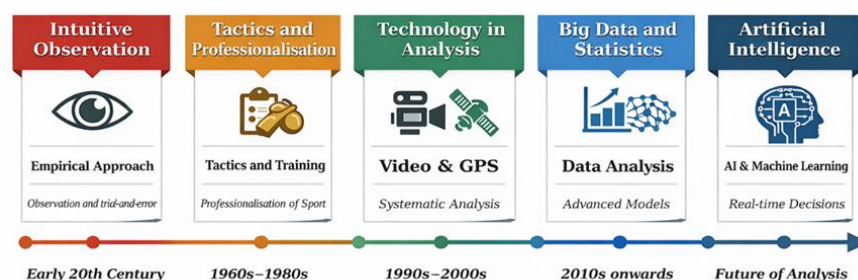


Figure 1. Stages describing the evolution of analysis in football (author's own elaboration)



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Stage 1. Early approaches to football analysis (1863–1924). Observation and intuition as the main method

During the early years of football, performance analysis was carried out mainly through direct observation and the intuition of coaches and players, with qualitative studies focused on general tactics, individual skills, and decisions during play (Memmert et al., 2019; Hughes & Bartlett, 2002). Strategies were developed from accumulated experience and the observation of previous matches, without advanced statistical or technological tools, reflecting an eminently intuitive approach. This initial stage coincided with a key period marked by the evolution of the rules, the institutionalization of norms, and, subsequently, the growing professionalization of the sport (García-González et al., 2019; Sarmiento et al., 2018).

The formalization of football rules had a decisive influence on the way teams competed, the style of play, and match outcomes. In its early years, the absence of a defined regulatory framework allowed a high degree of violence and disorganization, with a predominance of individual play over collective strategy. The creation of the International Football Association Board (IFAB) in 1886 and its integration with FIFA in 1913 established universal rules applicable to official competitions, including the figure of the referee and the systematization of sanctions, marking a turning point in the regulation of football (Collins, 2015; Sarmiento et al., 2018).

Among the most relevant changes during this stage were:

1869–1881: introduction of the direct free kick, definition of the goalkeeper's functions, standardization of the ball, appearance of referees, use of shin guards, first sendings-off, and use of the whistle.

1882–1899: throw-in with both hands, sanctioning of professionalism, creation of the English league, installation of nets in goals, regulation of the penalty area, and sanctioning of penalties.

1902–1919: definition of lines on the field of play, foundation of FIFA, incorporation of football into the Olympic Games, regulation of kick-offs and walls at free kicks.

These regulatory transformations favoured the evolution of football from more individualized, physically disorganized, and scarcely standardized forms of play towards



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a progressively rationalized, institutionalized sport oriented towards collective play. The consolidation of refereeing, the homogenization of rules, and the tactical evolution associated with the development of passing and combined play contributed not only to structuring modern football and reinforcing principles of discipline, control, and fair play, but also to promoting greater tactical and strategic organization of the game (Döllinger, 2026; Tenèze et al., 2015; Wilson et al., 2025; Swain & Harvey, 2012).

In this context, the progressive regulation of football favoured the transition from predominantly individual actions towards increasingly coordinated and complex collective models, facilitating a more systematic understanding of competitive dynamics by coaches and teams. In parallel, the partial reduction of the violence and disorder present in the early stages of the sport generated a more stable and predictable competitive environment, laying the foundations for the first forms of structured observation of the game and, subsequently, for the development of systematic methods of sports performance analysis (Hughes & Bartlett, 2002; Memmert et al., 2019).

Stage 2. Development of tactical analysis and professionalization (1925–1959)

Tactical systematization and emergence of the modern coach

Between 1925 and 1959, football analysis evolved towards a more systematic understanding of tactical structures and the collective organization of play. The consolidation of competitive leagues and the progressive formalization of rules encouraged coaches and teams to develop more structured playing systems in order to obtain strategic advantages. This process marked a transition from predominantly intuitive forms of observation towards more organized approaches based on the identification of tactical patterns and recurrent collective behaviours (Russell, 2011).

During this period, the figure of the coach acquired growing relevance in the preparation and direction of collective performance. Beyond deciding line-ups or positional distributions, coaches began to structure tactical principles, organize training, and adjust decisions during the match, which favoured progressive specialization in technical, methodological, and strategic knowledge (Kelly & O'Regan, 2021). Consequently, team organization ceased to depend exclusively on inherited traditions and came to be grounded in more explicit criteria regarding spatial occupation, collective balance, and tactical adaptation to the opponent.



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The growing importance of the coach also favoured greater appreciation of practical knowledge derived from competitive experience and continuous observation of the game. Several studies have indicated that many elite coaches develop methodological principles and forms of tactical interpretation before these are fully systematized by sport science, acting as producers of applied knowledge within the competitive context itself (Haugen, 2021). In this sense, decision-making began to integrate rational and intuitive components, especially in situations characterized by time pressure, uncertainty, and incomplete information. Research on decision-making styles shows that coaches with elite experience tend to combine analytical reasoning and expert intuition more frequently, suggesting that repeated exposure to complex tactical problems favours specific forms of perception and interpretation of the game (Giske et al., 2013).

Nevertheless, the growing centrality of the coach also introduced potential limitations associated with human reasoning and subjectivity in decision-making. Recent studies have shown that certain cognitive and behavioural biases, such as overconfidence, may affect interpretative processes and condition collective performance (Zavertiaeva et al., 2018). From this perspective, the historical development of the modern coach anticipates a tension that remains present in contemporary performance analysis: the coexistence of expert knowledge, intuition, and cognitive limitations.

The consolidation of the first modern tactical systems reflects this strategic evolution. Although primitive formations such as 1-2-7 or 2-2-6 provided only a basic positional order, the progressive adoption of structures such as the “pyramid” (2-3-5) and later the WM system evidenced more sophisticated tactical thinking, oriented towards balancing defensive and offensive functions and improving collective coordination (Perarnau, 2021).

Professionalization and competitive organization

The growing professionalization of football progressively transformed the competitive structure of the sport and favoured greater organizational complexity. The expansion of professional leagues, the commodification of the game, and the international mobility of players and coaches facilitated the dissemination of tactical strategies, training methodologies, and forms of competitive organization among clubs and countries (Poli,



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2010; Lombardi et al., 2020). This process contributed to a certain standardization of practices and consolidated a more strategic view of collective performance.

In parallel, structural differences between clubs began to emerge from the unequal availability of economic resources, talent, and organizational capacities. Although competitive rules were common, several studies have shown that factors such as squad composition, financial capacity, and the organizational quality of the club significantly condition sporting performance and competitive balance (Gerhards & Mutz, 2017). In this context, performance ceased to be interpreted exclusively as the result of observable individual actions and also came to be understood as a consequence of broader organizational structures and institutional dynamics.

The international mobility of footballers and coaches also favoured processes of knowledge transfer among sports organizations. The circulation of players involved not only the movement of talent, but also the dissemination of tactical, methodological, and cultural experiences across different competitive contexts (Lombardi et al., 2020). As a result, professional football progressively began to take shape as a complex organizational system in which competitive advantage depended not only on the available players, but also on the institutional capacity to integrate resources, knowledge, and organizational learning.

Initial development of training methodologies

In parallel with tactical evolution and the professionalization of football, more structured forms of training began to develop, aimed at improving collective organization and performance consistency. Although the methods used during this period were still far from the later level of scientific systematization, preparation progressively ceased to be based exclusively on informal repetition or individual experience and began to incorporate more organized criteria for physical, technical, and tactical planning (Kelly & O'Regan, 2021).

This evolution was closely linked to the growing prominence of the coach as the figure responsible not only for directing the match, but also for structuring processes of preparation and collective learning. Consequently, training began to be understood as a space for developing tactical principles, coordinating collective behaviours, and adapting team performance to different competitive contexts. Thus, preparation ceased to focus



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solely on isolated individual capacities and moved towards more integrated forms of collective work.

The progressive organization of training also favoured a more stable understanding of the relationships between preparation, tactical behaviour, and competitive performance. Although advanced monitoring systems and sophisticated quantitative methodologies did not yet exist, early forms of systematic observation began to emerge, aimed at evaluating collective behaviours, correcting recurrent errors, and reinforcing specific playing patterns. From this perspective, training constituted one of the first spaces where observation, interpretation, and performance adjustment began to be integrated in a relatively structured way.

In addition, the growing professionalization of football increased the need to integrate physical, technical, and tactical dimensions within more coherent and organized preparation processes. Contemporary research on contextualized training has reinterpreted these transformations as antecedents of later models of periodization and integrated training, in which physical and tactical preparation are understood as interdependent dimensions of collective performance.

Early structural performance variables

At this stage, different structural variables related to collective performance also began to be recognized more explicitly. Factors such as team cohesion, shared competitive experience among players, organizational stability, and the availability of technical and human resources began to be associated with differences in team performance and competitive consistency (Espitia-Escuer & García-Cebrian, 2020). This process favoured a progressively more multidimensional understanding of football performance.

In parallel, training planning began to acquire a more organized and integrated structure. Although the methods used still lacked contemporary methodological rigour, the growing professionalization of the sport promoted forms of preparation that combined physical, technical, and tactical aspects in a more coherent way, anticipating later developments related to periodization and contextualized training (Kelly & O'Regan, 2021).



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Likewise, cultural and environmental factors progressively began to be recognized as relevant elements in the development of performance and playing style. Subsequent research on sociocultural and ecological constraints has shown that the development of football skills depends not only on formal training programmes, but also on specific cultural contexts, motor experiences, and social dynamics that condition players' perception, creativity, and decision-making (Uehara et al., 2021; Vaughan et al., 2021).

Figure 2 presents a structural model of football performance in which organizational variables, training processes, player market dynamics, and technical-tactical and physical components interact, at both collective and individual levels, showing their influence on overall outcome and competitive balance.



Figure 2. Sufficient structural variables for R-R analysis (performance-result)

Transition towards early forms of systematic analysis

Consequently, during this period performance analysis evolved from the observation of isolated individual actions towards broader interpretations that incorporated tactical, organizational, and contextual dimensions of the game. Although analysis remained predominantly qualitative and based on the practical experience of coaches and players, this stage established the conceptual foundations for later forms of systematic performance analysis.

The evolution of football between 1925 and 1959 can therefore be interpreted as a transitional stage between the intuitive observation characteristic of the early years of the sport and the subsequent structured forms of observation, modelling, and interpretation of the game.

Stage 3. Technological advances and sophisticated analysis (1960–1979)

Incorporation of video into performance analysis



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Although television broadcasting began to expand from the mid-twentieth century, the relevant leap for performance analysis occurred when magnetic tape recording and, later, its operational availability in clubs and coaching staffs made it possible to review matches repeatedly, segment actions, and compare patterns across matches. This development forms part of the broader trajectory of sports notational analysis, whose historical antecedents preceded the systematic use of video, but which, with audiovisual recording, gained greater capacity for review, coding, and verification in real-game contexts (Eaves, 2015; Reilly, 2001).

From the 1960s onwards, audiovisual recording favoured more systematic analysis: coaches and analysts were able to identify tactical regularities, adjust match plans, and support player feedback with reviewable evidence. In this sense, video-notational analysis made it possible to observe football behaviours in natural, dynamic, high-pressure environments, partially overcoming the limitations of studies conducted in artificial or laboratory contexts (Caso et al., 2026). Nevertheless, the scope of the analysis remained conditioned by manual coding, the partial selection of events, and the difficulty of processing all available information comprehensively.

Observation of football and incomplete information

Understanding football through observation depends on the observer's position with respect to the performance of both teams and, especially, to the competitive process of a specific team. When the focus is on the play of both teams, observation tends to capture visible variables more easily, such as technical-tactical actions, movements, and positional organization, although from angles different from those of the players themselves. By contrast, those involved in preparation, such as coaches, analysts, and staff members, have close knowledge of their own team, but can only estimate the opponent's behaviour probabilistically. Therefore, analysis is conducted under inevitably incomplete information, which conditions interpretation and decision-making.

Depending on their link with the team and the preparation process, external observers, such as fans, journalists, or researchers; non-protagonist internal observers, such as coaches and analysts; and protagonist internal observers, namely the players themselves, can be distinguished. This position determines the degree of integration between what is observed and prior planning, ranging from a superficial non-integrated



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reading, to a professional reading weakly connected to preparation, an observation integrated into the process, or a player's self-referential perspective. This methodological caution is consistent with the literature on football performance analysis, which insists on incorporating situational, interactional, and contextual variables to avoid decontextualized interpretations of observational records (Sarmiento et al., 2014; Preciado et al., 2019; Travassos et al., 2013).

In all cases, the availability of information is partial, especially with respect to the opponent, which reinforces the need to interpret records cautiously and contextualize them. Consequently, observational data should be understood as partial approximations dependent on the competitive context, and not as a complete reproduction of the actual process of play.

Figure 3 represents the model of football performance observation according to the type of observer, the degree of integration with the competitive process, and the limitations derived from the information available during competition.

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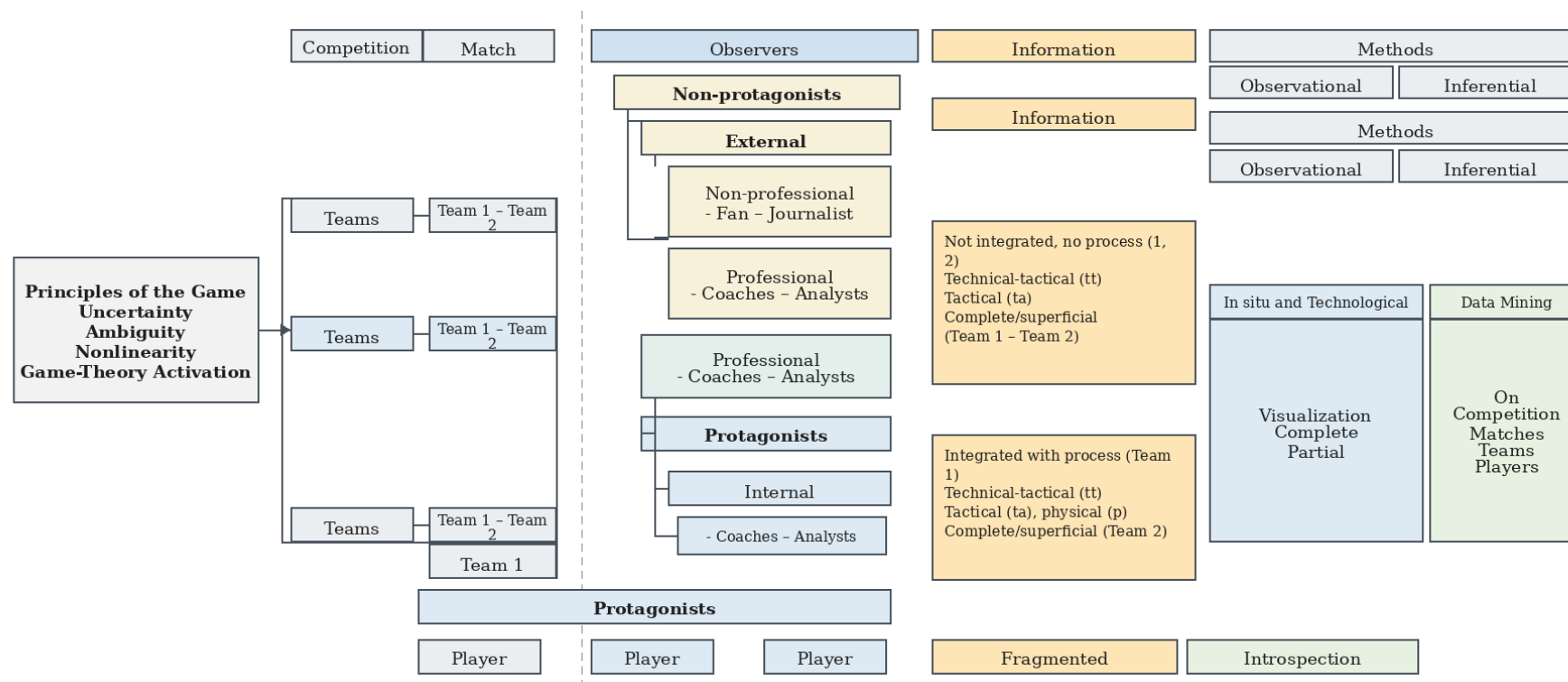


Figure 3. Observation, information, and methods in football (author's own elaboration).



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Analyst reasoning, biases, and causal attribution

The interpretation of performance in football is exposed to cognitive errors that affect the identification of causal relationships. This problem is not only technical, but also cognitive, since the literature on decision-making in sport shows that coaches, players, referees, and analysts reason under conditions of uncertainty, frequently resorting to heuristics and potentially being affected by biases derived from the way information is perceived, selected, or presented (Greenlees et al., 2007; Johnson, 2025; Ramanayaka et al., 2024). Confirmation bias may lead to privileging prior hypotheses over contradictory evidence, while the use of heuristics in uncertain environments increases the risk of generating premature conclusions within a dynamic and nonlinear system. In addition, each match constitutes a singular event that is highly dependent on the competitive context, which favours attribution errors when simplified explanations are extrapolated from specific sequences of play.

Within this framework, although it is possible to describe actions that precede a goal, the inherent ambiguity of the game limits the stability of these associations, since similar actions developed under comparable conditions do not necessarily guarantee the same outcome. Therefore, commonly used indicators, such as shots, possession, or field location, may show positive relationships with the outcome, although generally of moderate magnitude. The literature on goals and match analysis recommends differentiating between static descriptions of indicators and dynamic approaches that consider the sequence, context, and temporal evolution of actions (Pratas et al., 2018; Sarmiento et al., 2014). Likewise, attributing the outcome directly to available resources or to a single variable implies ignoring contingency and the simultaneous interaction of multiple factors.

Finally, performance emerges from reciprocal adaptation between opponents, since teams adjust their collective styles and individual actions according to the opponent and the development of the match. This logic of anticipation and response, close to strategic thinking and game theory, reinforces the need to interpret data in a contextualized and cautious manner. From the perspective of ecological dynamics, performance in team sports cannot be explained exclusively through isolated variables,



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but through the continuous interaction between players, teams, tasks, and competitive environment (Travassos et al., 2013). Consequently, uncertainty should not be understood as a defect external to analysis, but as a structural condition of football that requires probabilistic, transparent, and revisable conclusions (de Koning & Noordhof, 2019; Nimphius & Jordan, 2020).

Stage 4. Consolidation of technological analysis (1980–2010)

Video analysis software and recording tools

During the period 1980–2010, the analysis of football matches began to consolidate through the work of tactical analysts and coaches, who used systematic observation and the recording of performance indicators to evaluate the individual and collective behaviour of players and teams. This process is framed within a stage of transition from predominantly qualitative approaches towards more structured analysis models, laying the foundations for the subsequent development of video analysis software in modern football.

At this stage, performance analysis began to be oriented towards more systematic procedures for observing, coding, and categorizing technical-tactical actions, allowing specific events in the game to be recorded and relationships to be established between certain behaviours and competitive performance. The first notational analysis systems made it possible to evaluate actions such as passes, dribbles, controls, defensive behaviours, or attacking sequences, providing objective information for training planning and tactical decision-making (Papadimitriou et al., 2001; Thomas et al., 2009).

As a methodological synthesis of this process, Figure 4 represents the main phases of performance analysis in football, integrating the processes of observation, recording, analysis, and interpretation of the information obtained during competition. The model incorporates both natural and technological forms of observation and different analysis strategies based on intuition, statistics, and data mining, also differentiating between instantaneous interpretations and retrospective analyses of the game.



Original article. Original article. Evolution of performance analysis in football: towards a conceptual model across data, analysis, and interpretation. Vol. 12, no. 4; p. 1-22, August 2026.

<https://doi.org/10.55040/51zm5h50>



Figure 4. Observation, recording, analysis, and interpretation of the game (author's own elaboration)

Analysis could be based both on direct observation of plays and on the use of video analysis tools, which allowed attention to be focused on specific actions or general patterns of play. Instantaneous interpretation was associated with the coach's work during the match, whereas retrospective interpretation made it possible to develop deeper analyses oriented towards strategic decision-making and continuous performance improvement.

As discussed in the previous section, audiovisual review of the match opened the door to more systematic analysis. Between 1980 and 2010, this approach was consolidated through specialized software that facilitated the selection, coding, and comparison of relevant sequences of play. This process involved identifying key moments and segmenting the most significant actions for subsequent analysis. With technological progress, more sophisticated tools for recording, visualization, sequencing, and tracking actions on the field of play began to be developed.

The incorporation of these tools had a relevant impact on individual and collective performance, as it allowed technical errors to be identified, recurrent tactical patterns to be recognized, and competitive preparation to be optimized. In parallel, match analysis began to acquire a more defined methodological structure, integrating technical, tactical, and physical variables into progressively more complex evaluation models (Sarmiento et al., 2014).

Likewise, the evolution of the game itself drove the need for more advanced analytical tools. Retrospective research on Football World Cups between 1966 and 2010 showed a progressive increase in the speed of play, player density, and passing frequency, configuring competitive contexts that were more dynamic and complex from a tactical and physical perspective (Wallace & Norton, 2014). This increase in competitive



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<https://doi.org/10.55040/51zm5h50>

complexity favoured the development of analytical methodologies capable of capturing not only isolated actions, but also collective patterns and spatial relationships between players.

Stage 5. The era of Big Data and large-scale analysis (2011–present)

Data integration and advanced metrics

Since its beginnings, data collection in football has been a common practice, initially focused on quantifying results and key events during matches. The first football reports focused on recording basic aspects such as goals, corner kicks, shots, or the number of players involved in certain actions. Nevertheless, the extraction of relevant information from data processing preceded the first systematic efforts of statistical collection by sports organizations.

In this context, baseball historically consolidated itself as one of the pioneering sports in the application of advanced analytical approaches, especially through Sabermetrics, aimed at evaluating player performance through specific metrics. In football, one of the most relevant early advances occurred with the studies by Reep and Benjamin, who analysed the relationship between the number of passes and situations leading to goal scoring, giving rise to a quantitative approach to game analysis.

This approach evolved into notational analysis or performance analysis, making it possible to study both the individual performance of players and the collective performance of teams. However, the literature has indicated that traditional analysis based on isolated events was insufficient to capture the tactical complexity of football, as it depended on descriptive and, in many cases, decontextualized variables. In this regard, Sarmiento et al. (2014) noted the need to incorporate situational, interactional, and contextual variables to improve the validity of performance models.

The emergence of positional data, event data, and tracking systems represented a substantial change in the way the game is studied. New technologies make it possible to analyse collective behaviour, spatial occupation, defensive pressure, synchronization between players, distances between lines, possession models, and offensive and defensive tactical patterns. Thus, performance analysis ceased to be limited to counting actions and became oriented towards the dynamic interpretation of the game (Forcher et al., 2022; Teixeira et al., 2022; Goes et al., 2021).



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<https://doi.org/10.55040/51zm5h50>

Along these lines, several studies have demonstrated the potential of tracking data for analysing defensive behaviour. Pressure on the ball carrier, numerical superiority in zones close to the ball, compactness of the defensive block, and collective coordination appear as relevant variables for explaining defensive success and ball recovery (Forcher et al., 2024a; Forcher et al., 2024b; Forcher et al., 2022). These works show that Big Data not only expands the volume of available information, but also allows the construction of tactical indicators closer to the reality of the game.

Likewise, the identification of playing styles through dimensionality reduction techniques and unsupervised learning has made it possible to classify collective behavioural patterns, facilitating the analysis of tactical trends, match preparation, scouting, and training planning (Gu et al., 2025). In parallel, models based on positional data have shown capacity to predict results or evaluate offensive and defensive principles from tactical variables derived from player movement (Goes et al., 2021).

The consolidation of these methodologies has also promoted processes of standardization of physical and tactical metrics. Yunus & Aditya (2025) highlight that the combination of quantitative statistics, data mining, and machine learning has transformed scouting and performance evaluation, even enabling predictive models with high levels of accuracy in certain playing positions. Similarly, Zambom-Ferraresi et al. (2018) identified robust indicators associated with competitive performance in the main European leagues, underlining the relevance of offensive metrics such as assists, shots on target, and passing accuracy.

Nevertheless, the growth in data volume has also generated new methodological problems. Recent literature insists that having large amounts of information does not automatically guarantee better decisions. Limitations persist regarding data quality, metric standardization, interoperability between providers, the absence of common taxonomies, unequal access to advanced technologies, and the difficulty of translating raw data into useful knowledge for coaches, analysts, and managers (Lolli et al., 2025; Goes et al., 2021; Rein & Memmert, 2016). Along these lines, Aguilar (2026), through a systematic review and bibliometric analysis of the five major European leagues, identified high methodological heterogeneity and limited capacity of current models to represent



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<https://doi.org/10.55040/51zm5h50>

the specific tactical singularity of teams, while a relevant gap remains between academic production and its practical application in professional football.

In this regard, Mackenzie & Cushion had already pointed out important methodological limitations in studies of football performance analysis, such as insufficient sample sizes, omission of relevant external variables, and biases derived from weak research designs. These criticisms remain valid in the era of Big Data, where the problem lies not only in collecting more data, but in constructing models that are interpretable, contextualized, and useful for sports decision-making.

Artificial intelligence and performance prediction

A fundamental step in the evolution of data analysis in football has been the development of advanced technologies for tracking events and trajectories during competitions. The growing availability of services provided by specialized platforms, together with advances in software, sensors, computer vision, and predictive models, has transformed sports analysis into a field increasingly dependent on data science.

In this context, the so-called data industry applied to football has emerged, made up of data providers, clubs, federations, analysts, coaching staffs, journalists, technology companies, and scouting departments. These platforms offer detailed metrics on individual and collective performance, facilitating decision-making in areas such as talent selection, tactical planning, injury prevention, opponent analysis, and the economic valuation of players (Yunus & Aditya, 2025; Primus & Karlsson, 2025; Lolli et al., 2025).

The incorporation of artificial intelligence and machine learning has added a new layer of analysis by enabling the detection of complex patterns, the prediction of events, and the generation of decision-support models. Recent reviews show that applications of AI in football have expanded rapidly since 2017, especially in areas such as outcome prediction, tactical analysis, talent identification, computer vision, injury prevention, simulation, and reinforcement learning (Klemp et al., 2026; Hoseinzadeh et al., 2026; Moya et al., 2025; Pu et al., 2024).

Among the most relevant advanced metrics is expected goals or xG, which estimates the probability that a shot will result in a goal. Recent studies have improved this metric through multilayer neural networks, explainable statistical models, and algorithms such as XGBoost, incorporating variables related to location, shooting angle,

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defensive pressure, trajectory, and tracking data (Méndez et al., 2023; Cefis & Carpita, 2025). These approaches show how AI makes it possible to refine traditional indicators and increase precision in the evaluation of offensive performance.

Similarly, models have emerged aimed at valuing possession, ball progression, and transitions. Metrics such as expected possession value or expected ball gain make it possible to quantify the balance between risk and reward in match situations, especially during offensive and defensive transition phases (Forcher et al., 2025). Other works have applied temporal convolutional networks to automatically estimate ball possession from tracking data, reducing dependence on manual recording and improving the accuracy of event coding (Borghesi et al., 2023).

More advanced models of sequential event prediction have also been developed, such as those based on Transformer architectures and spatiotemporal processes, capable of anticipating the type of action, the area of the field, and the time interval between events. This type of approach makes it possible to move from a static analysis of performance to a more dynamic understanding of action chains and possession efficiency (Yeung et al., 2025a).

Artificial intelligence has also favoured the development of open platforms and collaborative ecosystems for the spatiotemporal analysis of the game. OpenSTARLab is an example of this approach, integrating tools for event modelling, deep learning, and reinforcement learning oriented towards tactical analysis and the simulation of actions in football (Yeung et al., 2025b).

However, the literature warns that artificial intelligence should not be understood as an automatic solution. Some studies underline that excessively complex or black-box models do not always offer better predictions or prove more useful for football professionals. In many cases, interpretable models, built with well-selected variables and expert knowledge, may provide better decision-support tools than algorithms of high complexity but low transparency (Hecksteden et al., 2026; Beato et al., 2025).

In addition, the automation of analysis raises relevant challenges in terms of reliability. Automatic event detection, such as passes or shots, may present variable levels of accuracy depending on the quality and dependence of the data used, which requires rigorous validation of algorithms before applying them in professional contexts



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(Bischofberger et al., 2024). Added to this are problems of access to public databases, high costs of tracking systems, dependence on private providers, and inequalities between clubs with different technological resources (Yeung et al., 2025b; Lolli et al., 2025).

Consequently, the era of Big Data and artificial intelligence has significantly expanded the possibilities of football analysis, but it has also shifted the problem towards data governance, methodological quality, model interpretability, and the capacity of clubs to transform information into operational knowledge. Therefore, the real value of these technologies lies not only in predicting results or automating processes, but in integrating them critically within solid theoretical frameworks, such as ecological dynamics, which understands performance as the result of continuous interactions between players, teams, environment, and competitive task (Travassos et al., 2013).

Discussion

The results of this review make it possible to interpret the evolution of performance analysis in football not merely as a succession of technological innovations, but as an uneven development of three interdependent levels: descriptive, analytical, and interpretative. Across the different historical stages, progress has been especially intense at the descriptive and analytical levels, favouring an unprecedented expansion of the capacity to record, quantify, and model the game. However, this progress has not translated proportionally into an equivalent improvement in the overall understanding of performance or into a stable capacity for prediction and decision-making (Salmon & McLean, 2020; McLean et al., 2017).

In this context, the increase in methodological sophistication has simultaneously increased the interpretative complexity of analysis. The incorporation of advanced metrics, positional data, predictive models, and artificial intelligence expands the capacity to detect regularities and describe collective behaviours (Low et al., 2020; Teixeira et al., 2025), but continues to operate on necessarily partial representations of the game. As a consequence, greater instrumental precision does not by itself guarantee greater explanatory validity, especially in a system characterized by dynamic interactions, reciprocal adaptation between opponents, and strong contextual dependence (Dutt-Mazumder et al., 2011; Silva et al., 2016).



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<https://doi.org/10.55040/51zm5h50>

From this perspective, the results reinforce the existence of structural limits in the modelling of football. The nonlinear nature of the game, the impossibility of having complete information, and the difficulty of establishing stable causal relationships restrict the generalizability of analytical models (Kim et al., 2019; Lames et al., 2021). Likewise, interpretative processes remain conditioned by cognitive, strategic, and situational factors that cannot be fully formalized through quantitative approaches (Augustine et al., 2025).

Consequently, the evolution of performance analysis cannot be understood as a linear process of reducing uncertainty, but as a progressive displacement of its limits. As descriptive and analytical capacities increase, the main restrictions of the system move towards the interpretative level, where contextualization and decision-making continue to depend on processes that are only partially formalizable. In this sense, the tension between analytical capacity and contextualized interpretation constitutes a structural feature of performance analysis in football (Salmon & McLean, 2020; Dutt-Mazumder et al., 2011).

This approach also allows the role of the analyst and the coach within the contemporary data ecosystem to be reinterpreted. Far from being replaced by predictive models, both act as agents responsible for selecting, hierarchizing, and contextualizing the available information. Expert judgement does not operate outside analytical models, but as a necessary integration mechanism for translating quantitative representations into decisions coherent with the competitive logic of the game (Corsie et al., 2024; Mehta et al., 2024).

Likewise, comparison between historical stages shows that the evolution of analysis is not due solely to an increase in technical precision, but also to transformations in the way performance is represented. Whereas the initial stages offered less systematic but more integrated approaches to the game, recent stages tend to decompose performance into specific variables and isolated metrics. This process expands descriptive capacity, but also increases the risk of analytical fragmentation and loss of contextual coherence (McLean et al., 2017; Augustine et al., 2025).

In parallel, recent approaches based on spatiotemporal data and collective dynamics have made it possible to represent emergent interactions between players, subgroups, and teams with greater precision (Goes et al., 2021; Vilar et al., 2013).



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Nevertheless, even these models continue to face restrictions derived from contextual variability and the adaptive nature of collective behaviour, which limits the stability of their inferences and their capacity for generalization (Low et al., 2020; Silva et al., 2016).

Consequently, the main problem of performance analysis currently does not lie in the scarcity of data, but in the structural limits associated with their interpretation and application. In a competitive environment characterized by uncertainty, continuous adaptation, and strategic interaction, the value of analysis does not reside exclusively in its predictive capacity, but in its contribution to the contextualized improvement of decision-making. From this perspective, the future of performance analysis will probably depend less on the accumulation of new metrics and more on the capacity to integrate complex analytical models with contextualized interpretative processes and applied expert knowledge (Teixeira et al., 2025; Mehta et al., 2024).

Future perspectives of performance analysis in football

The future evolution of performance analysis will probably be marked by an increasing integration of multimodal data, artificial intelligence, and dynamic models capable of combining tactical, physical, and contextual information in increasingly complex analytical systems. This development will allow the descriptive and diagnostic capacities of analysis to be expanded, as well as operational recommendations to be generated in highly demanding competitive contexts.

Nevertheless, these advances will continue to face limitations derived from the nature of the game itself. The need to simplify, select, and parameterize variables implies that any analytical model will continue to represent only part of the competitive system. Consequently, the main future challenge will not consist solely of increasing the amount of data or the computational complexity of models, but of developing approaches capable of balancing analytical precision, interpretability, and practical applicability.

From this perspective, technological development will foreseeably continue to shift the limitations of analysis towards the interpretative plane, reinforcing the need to integrate tactical knowledge, contextualization, and expert judgement into decision-making processes.



Original article. Original article. Evolution of performance analysis in football: towards a conceptual model across data, analysis, and interpretation. Vol. 12, no. 4; p. 1-22, August 2026.

<https://doi.org/10.55040/51zm5h50>

Practical implications for performance analysis

The results of this review suggest that advanced metrics and data-based models should be used as decision-support tools and not as autonomous systems for interpreting the game. Their value depends on the capacity to contextualize information within the tactical and strategic demands of each competitive situation.

In applied terms, performance analysis requires the integration of quantitative information, tactical knowledge, and expert judgement in processes such as scouting, match preparation, and competitive evaluation. Consequently, the main challenge does not lie solely in accessing more data, but in transforming that information into decisions coherent with the logic of the game.

Conclusions

This study has analysed the evolution of performance analysis in football from a historical and conceptual perspective, proposing a model structured across three interdependent levels: descriptive, analytical, and interpretative. The results show that technological development has significantly increased the capacity to record and model the game, but without eliminating the structural limitations derived from its dynamic, contextual, and strategic nature.

From this perspective, the evolution of performance analysis does not imply a progressive reduction of uncertainty, but rather a displacement of its boundaries towards the interpretative plane. Consequently, the value of analysis does not reside exclusively in its predictive capacity, but in its contribution to the contextualized improvement of decision-making under conditions of structural uncertainty.

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