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The Influence of Technological Applications on the Fairness of Decision-Making in Football Matches

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Abstract: With the evolution of football tactics and the intensification of match demands, traditional refereeing reliant on subjective judgment increasingly falls short of meeting the modern game's rigorous standards for fairness. To mitigate the impacts of erroneous and missed decisions on match outcomes, technology-assisted refereeing has progressively been integrated into football competitions. Innovations such as Goal-Line Technology (GLT), Video Assistant Referee (VAR), and Semi-Automated Offside Technology (SAOT) have played a pivotal role in enhancing the accuracy and equity of officiating. However, the deployment of these technologies also introduces challenges including decision-making delays, substantial financial costs, and the continued dependence of certain rulings on subjective interpretation. This paper examines the contextual backdrop, positive impacts, and inherent limitations of technological interventions in football officiating, while prospectively exploring the development of artificial intelligence-assisted refereeing systems. It explores how to achieve a judicious balance among fairness, efficiency, and spectator experience, thereby offering theoretical guidance for the technological advancement of the sport.

Keywords: Technology-Assisted Refereeing; Referee; Technology; Football

1. Introduction

As the world's foremost sport, football commands an immense global fanbase, its influence unparalleled. Competitions such as the FIFA World Cup, the top five European leagues, and the UEFA Champions League represent the highest level of football. With the evolution of tactics and techniques, the game has accelerated in pace and intensified in physicality, thereby imposing greater challenges on officiating. Consequently, erroneous and missed calls frequently occur, significantly affecting the outcomes of matches. For instance, the infamous "Hand of God" incident involving Maradona during the 1986 World Cup semifinal, or England's shot, in the 2010 World Cup Round of 16, which struck the crossbar and crossed the goal line, was not awarded, depriving the team of an equalizing opportunity. Moreover, contentious decisions regarding offside and penalty calls recur with notable regularity. Although such errors, as elements of unpredictability, inject drama and captivate countless spectators, a single erroneous verdict can shatter years of collective effort for the players involved.

The advent of technological advancements has addressed myriad human limitations, enhancing convenience in daily life and bolstering fairness and spectacle across numerous sporting events [1]. Historically, football officiating has relied primarily on the "human perspective", a method conducive to smoother gameplay and minimized interruptions due to technology checks, yet susceptible to misjudgments and oversights. To uphold the integrity of the competition and mitigate the consequences of officiating errors for both teams, innovations such as Goal-Line Technology (GLT), Video Assistant Referee (VAR), and Semi-Automated Offside Technology (SAOT) have been progressively integrated into the football arbitration framework.

2. The Application Background of Technological Officiating

2.1 Goal-Line Technology

Initially, the determination of whether the ball had entirely crossed the goal line was aided by assistant referees positioned along the sidelines, offering a more parallel vantage point. However, this approach had significant limitations; the assistants' distance from the goal line, coupled

with rapid ball speeds and player obstructions, often led to erroneous or missed judgments. Consequently, additional officials known as additional assistant referees (positioned on the goal line) were introduced. Positioned closer to the goal than sideline assistants, these referees were better equipped to monitor fouls within the penalty area and ascertain goal-line decisions. Yet, even they remained vulnerable to challenges imposed by the velocity of play and obstructed sightlines. Moreover, incorporating these additional officials increased logistical and financial burdens [2]. Against this backdrop, and to enhance fairness while minimizing subjective error, FIFA formally endorsed the implementation of Goal-Line Technology (GLT).

GLT made its inaugural appearance during the 2012 FIFA Club World Cup. This system involves embedding sensor devices within the goalposts and crossbar. When the ball fully crosses the goal line, an instantaneous signal is transmitted directly to the referee's watch, confirming the goal without reliance on external alerts. This innovation ensures swift and precise judgments without interrupting the flow of the match [3].

2.2 Video Assistant Referee (VAR)

The perspective of on-field referees is inherently constrained, often subject to significant limitations. Spectators, observing matches through broadcasts, frequently critique referees' decisions from an omniscient "God's-eye view". Minor infractions such as fouls and offside rulings are particularly susceptible to inaccuracies due to the referee's distance and line of sight. Such misjudgments, including erroneous issuance of yellow or red cards, can directly or indirectly alter the course of a contest. Even the addition of assistant referees positioned along the goal line did little to fully overcome these inherent shortcomings.

Prior to its integration into football, VAR technology had been predominantly employed in other sports such as basketball, tennis, and badminton. In basketball, referees may initiate video review at any point during the game, with a centralized review team empowered to rule on contested decisions. Similarly, tennis and badminton utilize video systems mainly to ascertain whether the ball or shuttlecock lands within boundaries.

In March 2018, FIFA officially announced the introduction of VAR at the 2018 Russia World Cup, heralding a revolutionary transformation in football—a definitive entry into the technological era. Preceding tools such as communication headsets, GLT, and electronic flagging systems scarcely influenced match outcomes as profoundly as VAR [4].

At its inception, the VAR system incorporated 33 cameras around the pitch—including eight dedicated slow-motion viewpoints and two specialized offside cameras. Each match is supported by a four-person VAR team: one lead official (the VAR) who monitors the match footage and has overall responsibility, assisted by three assistants: one coordinating communications, one specializing in offside situations, and one focusing on potential penalty incidents and other contentious events. Additionally, four video replay operators vigilantly handled 14 monitors. The VAR technology synthesizes live footage with virtual reconstructions, employing 3D renderings to meticulously replicate match events, relaying precise information to the on-field referee via wireless communication [5]. Currently, VAR intervention is authorized exclusively for four categories of match-changing scenarios: "goal or no goal", "penalty awarded or not awarded", "direct red card incidents (excluding second yellow card offenses)", and "cases of mistaken identity in disciplinary actions". These four categories are further divided into two types based on objectivity/subjectivity: decisions that can be made by VAR review alone, and those that require the on-field referee to review the footage before making the final call [6].

2.3 Semi-Automated Offside Technology (SAOT)

In football, the responsibility of adjudicating offsides initially rested with the assistant referees stationed along the sidelines. These assistants were tasked with maintaining their positioning in line with the second-last defender of the opposing team, a stance intended to enhance observational accuracy compared to the center referee. However, as tactical complexity intensified and the tempo of matches accelerated, maintaining precise alignment became increasingly challenging. Furthermore, visual obstructions and other objective factors frequently compromised the assistant referees' ability to render correct offside decisions, thereby casting doubt on the fairness of the

competition.

Since the formal introduction of the VAR system, offside controversies have decreased considerably, improving the overall fairness of offside adjudications. Nevertheless, this advancement introduced new challenges. VAR does not intervene in every potential offside situation; it only becomes involved when a goal or penalty is contingent upon a possible offside infringement. Such interventions invariably prolong the pause in play, subjecting players and spectators alike to extended moments of suspense and disrupting the fluent rhythm of the game. Thus, while technology has enhanced the accuracy of offside judgments, "efficiency" has emerged as a critical issue.

Semi-Automated Offside Technology (SAOT) was unveiled at the 2022 Qatar World Cup as a refinement built upon the foundational VAR system, effectively addressing the efficiency dilemma associated with offside adjudications [7]. This system employs twelve cameras mounted beneath the stadium roof to track the ball and 29 data points on each player's body in real-time, capturing movements at an impressive rate of 50 times per second. Through this precise method, the technology meticulously determines the ball's exact position alongside the players' locations and bodily postures. The match ball deployed at the Qatar World Cup incorporated an embedded sensor within its core, transmitting data at a frequency of 500 times per second, thereby allowing for precise identification of the exact instant the ball is played. Upon detecting an offside offense, SAOT instantly issues an offside alert to the video referees and automatically generates graphical coordinates representing the players' positioning and body orientation at the moment of the infraction. The offside line is then dynamically annotated within the system's visuals. Subsequently, the video referees review the automatically generated imagery and, upon validation, relay their judgment to the on-field referee, who makes the final decision. This technology also produces a three-dimensional schematic illustrating player positions and postures at the critical moment, which is broadcast on stadium big screens and live transmissions, ensuring that both attending fans and viewers at home can transparently comprehend the basis of the call. Empowered by this technological leap, offside rulings during the Qatar World Cup are poised to become markedly swifter and more accurate, thereby preserving the seamless flow of matches while minimizing contentious disputes [8].

3. The Positive Impact of Technological Applications on the Fairness of Officiating

The revisions made to the rules of football are fundamentally aimed at upholding the principle of fair play. Nevertheless, when human referees serve as arbiters, inherent limitations such as visual blind spots and subjective judgments inevitably arise. To minimize controversies stemming from subjective officiating decisions, the integration of technological aids into the adjudication process has become both an inevitable and necessary progression in accordance with the times.

Since the introduction of GLT, disputes regarding whether a goal was scored have been virtually eradicated. Referees on the field no longer need to subjectively ascertain if the ball has wholly crossed the goal line; instead, they await confirmation from the system. This innovation not only eliminates the recurrence of "goal-line mysteries" but also allows referees to redirect their focus toward other critical areas of the game, such as monitoring potential fouls.

Among the four intervention moments of the VAR system during matches, rulings concerning the validity of goals and penalty decisions are paramount. Correct verdicts in these instances profoundly influence the trajectory and outcome of contests. For example, in the Asia World Cup qualifier on November 14, 2024, between China and Bahrain, Bahrain appeared to net a goal on a counterattack in the 87th minute, eliciting despair among Chinese supporters. However, VAR promptly intervened to alert the head referee of an offside infringement during Bahrain's offensive play, nullifying the goal and leveling the score at 0-0. Minutes later, in the 91st minute, China executed a dramatic "counter winner", securing an arduous away victory and thereby markedly enhancing their prospects of advancing to the World Cup finals. This instance underscored the immense significance of VAR's intervention: the offside was subtle and had gone unnoticed by the assistant referee. Absent VAR's involvement, China's defeat would have severely diminished their qualification chances.

The SAOT system is meticulously designed with a singular purpose—to assist adjudications of offside infractions—and represents an upgraded iteration of VAR's offside rulings. This system boasts superior accuracy and significantly

reduced decision times, effectively enhancing the fluidity of play and preserving the spectacle of the match by minimizing disruptions caused by offside reviews [9].

Upon the advent of technological assistance on the football pitch, the referees' "field of vision" has been dramatically expanded, nearly achieving comprehensive, unobstructed oversight. Even when initial human error occurs in officiating, technology enables real-time rectification, thereby elevating the overall fairness of the competition and substantially reducing the incidence of "unjust decisions" on the field [10].

4. Challenges and Controversies Surrounding the Fairness of Decisions Amid Technological Applications

With the commencement of technological interventions in football matches, the frequency of contentious decisions has markedly diminished, concomitantly reducing the inherent unpredictability of outcomes. As elucidated in the ancient text *I Ching*, all phenomena possess dual, opposing facets—every entity embodies both strengths and shortcomings. While the incorporation of technological tools has undeniably enhanced the objectivity of match officiating and facilitated the rectification of decisions, it has simultaneously engendered a spectrum of ancillary issues. Effectively addressing the adverse ramifications arising from the use of these technologies has thus emerged as a focal point of scholarly discourse.

4.1 Controversies Stemming from Technology - Assisted Officiating

As an emergent arbiter underpinning on-field decision-making, technology-assisted systems principally serve to furnish officials with augmented angles of perception. In relatively objective scenarios—such as determining whether a goal has been scored, whether offside occurred prior to the goal, or whether the ball crossed the boundary lines—these systems afford precise adjudications. Nevertheless, numerous other circumstances necessitate referees to consult video replays and integrate their subjective discernment before issuing rulings, including assessments of whether an offside-positioned player actively engaged in the play or influenced opponents, and whether a foul has actually transpired. Consequently, even with the aid of technological intervention, decisions may continue to provoke debate and dissent.

4.2 The Dilemma of Utilizing Technology-Assisted Systems

In the era preceding the deployment of technological aids, events unfolding on the pitch were fleeting and irreversible, compelling referees to render instantaneous decisions. This demanded monumental acuity and presented a formidable challenge, often leading to erroneous or overlooked calls—factors that contribute substantially to the sport's intrinsic uncertainty. Such unpredictability, intertwined with the fluidity of play, has long captivated legions of ardent supporters.

With the advent of technology-assisted systems, while the incidence of misjudgments and omissions has been curtailed, a new predicament has emerged: frequent interruptions during matches. For instance, in the 2018 World Cup encounter between France and Australia, an offensive player was fouled inside the penalty area, yet the on-field referee initially refrained from awarding a penalty. The subsequent intervention by VAR entailed a video review lasting approximately five minutes before the penalty was finally granted. This protracted pause disrupted the natural flow of the game, detracting from the immersive experience for the audience.

Although these technological systems have existed for several years, their adoption remains far from universal. Some competitions implement solely GLT, while others eschew technological assistance altogether. Widespread utilization is largely confined to premier international tournaments and certain elite domestic leagues. The primary impediments to broader dissemination include prohibitive costs and logistical challenges posed by stadium infrastructure incompatible with system installation. Addressing these financial and technical barriers, thereby fostering greater accessibility and integration of technology-assisted officiating, will undoubtedly constitute a vital objective for future research and development endeavors.

5. Future Developmental Trajectories of Technological Applications

The integration of technology-assisted systems in football officiating epitomizes an inevitable convergence of contemporary progress and technological advancement, exerting profound

influence upon the sport. Nonetheless, certain controversies and shortcomings persist. These objective criticisms will serve as pivotal foundations for the innovation of subsequent technologies, ultimately diminishing disputes in match adjudications and enhancing the equity of competition.

Presently, the systems employed function predominantly as supplementary tools aiding referees, with the ultimate judgment still vested in their discretion, thereby permitting the persistence of pronounced subjective interpretation. The forthcoming trajectory in technological evolution aims to harness artificial intelligence to quantify officiating parameters and establish standardized criteria for rulings on the field. Yet, given that such technologies cannot wholly supplant the referee's subjective judgment, the proportional balance between technological input and human decision-making will undoubtedly emerge as a critical issue for future exploration.

Currently, the systems in use serve solely as adjunct tools to assist referees, with the ultimate decision-making authority remaining firmly in the hands of the officials themselves, thereby perpetuating the presence of inherently subjective judgments. The future development of technology-assisted systems will likely focus on leveraging artificial intelligence to quantify the parameters of on-field rulings and establish standardized criteria. Nonetheless, as these technologies can never fully supplant the nuanced discretion of human referees, striking an appropriate balance between technological intervention and human judgment will undoubtedly constitute a paramount challenge moving forward.

6. Conclusions

With the continuous advancement of technology, football officiating has undergone a fundamental transformation—from relying predominantly on the subjective judgments of referees to embracing technology-assisted decision-making. Innovations such as Goal-Line Technology (GLT), Video Assistant Referee (VAR), and Semi-Automated Offside Technology (SAOT) have played a crucial role in enhancing decision accuracy and fairness, thereby safeguarding the integrity and appeal of the game. However, integrating these technologies has also introduced new challenges, including the persistence of certain subjective elements in decisions, delays in the adjudication process, and considerable financial costs.

Looking forward, the primary challenge lies in optimizing technology-assisted systems to maintain the fluidity of matches and enrich the viewing experience while advancing the standardization of officiating through artificial intelligence. Additionally, harmonizing technological tools with the indispensable subjective judgment of referees remains a vital issue to address. As efforts to improve fairness and efficiency in football refereeing continue, technology will assume an increasingly important role that demands deeper investigation and practical application.

In conclusion, the adoption of technology in football officiating not only responds to the evolving demands of modern competitive sports but also sets a new benchmark for fairness. Through ongoing technological refinement and thoughtful integration, football matches will be delivered to fans worldwide with greater precision, equity, and engagement.

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