NOVA IMS Information Management School

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## A Comprehensive Evaluation of Autonomous Referees in Sports

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Master Thesis

presented as partial requirement for obtaining a Master's Degree in Information Management

**NOVA Information Management School**

**Instituto Superior de Estatística e Gestão de Informação**

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# A COMPREHENSIVE EVALUATION OF AUTONOMOUS REFEREES IN SPORTS

by

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Master Thesis presented as partial requirement for obtaining the Master's degree in Information Management, with a specialization in Information Systems and Technologies Management

## Supervised by

Vitor Santos, PhD, NOVA Information Management School

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# STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism, any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledged the Rules of Conduct and Code of Honor from the NOVA Information Management School.

*Lisboa, 02/07/2025*

*Miguel Campos*

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To my friends, to Professor Vitor Santos, and a special mention to my family, who never gave up on me. Also, to everyone that supported me on this journey. Without them all, it wouldn't be possible.

# ABSTRACT

Technological advances are increasingly reshaping sports officiating, with growing debate around the potential implementation of autonomous referees. Understanding stakeholders' perspectives on these systems is essential to ensure their successful and accepted integration into sports. However, research exploring the acceptance and implications of fully autonomous referees across different sports remains limited. This study aims to evaluate stakeholder perceptions regarding the feasibility, fairness, and ethical considerations associated with completely automated refereeing systems. A quantitative, survey-based approach was conducted, targeting essential stakeholders including players, coaches, referees, and spectators. Respondents were surveyed to gather insights on their attitudes towards reliability, fairness, accountability, and practical implications of autonomous officiating systems.

Results indicate that stakeholders' acceptance primarily depends on their trust in the system's ability to ensure fairness and accountability rather than the nature or characteristics of specific sports. Contrary to expectations, sports with more objective rules were not necessarily seen as more suitable for automation. Instead, the findings underscore the importance of maintaining fairness, transparency, and human oversight within officiating processes. These insights suggest that sports organizations should pursue a cautious, phased integration of autonomous referees, favoring hybrid models that balance technological precision with human judgment. Future research is recommended to further explore these hybrid approaches to maximize fairness, accountability, and spectator enjoyment in sports.



# KEYWORDS

Autonomous referees; Sports technology; Stakeholder perception; Ethical considerations; Hybrid refereeing systems.

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# LIST OF ACRONYMS

**AA** - Assistant Referee

**ACM** - Association for Computing Machinery

**AI** - Artificial Intelligence

**CSL** - Chinese Super League

**EPL** - English Premier League

**FIFA** - Fédération Internationale de Football Association

**IFAB** - International Football Association Board

**IoT** – Internet of Things

**IS** - Information Systems

**VAR** - Video Assistant Referee

# 1. INTRODUCTION

## 1.1. BACKGROUND AND PROBLEM IDENTIFICATION

In many ways, modern technology simplifies everyone's lives. In today's environment, almost everything has become more comfortable and accessible due to technical advancements in nearly all areas of life (Omoregie, 2016). In the 21st century, more people are participating in sports than ever before, making it a universal language that unites citizens regardless of their roots, history, religious values, or economic status (Roy & Roy, 2017). Due to the demands of sports performance, technological devices now play a significant role for sports professionals. For instance, instant replay and other high-tech aids are incredibly helpful in assisting referees to make the correct call. Referees often use replay systems to verify if football players were offside (Cave & Miller, 2015; Spitz et al., 2020).

Also, the face of refereeing has changed dramatically with the increase of modern technologies. International federations of various sports have begun to introduce technological advancements to assist professionals and the referee's decision-making in order to increase player and audience interest. In international games, referees have used various technological tools like smartwatches, microphones, wireless microphones, smart glasses with built-in Hawk-Eye and Hot Spot technologies, multiple technical cameras, and video cameras, among numerous other devices that assist in making accurate decisions (Ryall, 2012).

Decisions made by a referee can influence the outcome of a game. In some situations, the direction of the game can be altered by a single decision. As such, it's common for the referee to be identified as the cause of a player's or team's failure and to be held accountable for influencing the outcome of the game by not enforcing the rules or even being biased. In this sense, referees have to respond almost instantaneously to dynamically unfolding events in a game, which may have many nuances, ambiguities, and uncertainties, creating a lot of pressure on their judgment (Tamir & Bar-eli, 2021).

However, these technologies serve as a complement to human action; thus, when the human referee makes a mistake or is uncertain about their decision, technology helps. But what if these technologies begin to make decisions in sports autonomously? This would be feasible in sports with more objective rules like tennis, volleyball, or padel. In football, this would be more complicated as there are more decisions based on interpretation, making it challenging to program any technology to act in this manner (Kolbinger & Lames, 2017; Spitz et al., 2020).

But would this fully autonomous approach be accepted by the key stakeholders in a game, like coaches and players? More than applying or evaluating the use of these technologies, which we have some examples of working well, this question would be the most critical to understand for the success and integration of autonomous technologies. Previous research highlights mixed perceptions about technological interventions, specifically about

transparency, interruption of the flow of the game and fairness perceptions (Kolbinger & Knopp, 2020; Lago-Peñas et al., 2019).

Therefore, the primary objectives of this research would be, firstly, to understand in which type of sports this would be possible, based on the feasibility of implementing autonomous refereeing; secondly, to evaluate in which sports it would make sense for such a change; thirdly, to assess whether this change would be approved by players and coaches; and finally, to analyze the potential ethical, practical and experiential impacts of implementing autonomous referees on the integrity, fairness and overall dynamics of sports competitions.

The methodological approach would be to analyze data from past experiences with technology in refereeing and understand which sports would best adapt to this change. It would also evaluate the pros and cons of this move. A structured surveys will be conducted to see if spectators, players, and coaches would approve of this change. In the end, this data would be interpreted to draw some conclusions on the subject regarding viability, acceptance and potential impact of autonomous referees across various sports contexts.

## 1.2. MOTIVATION

The motivation behind this research comes from the urgent need to improve fairness and consistency in sports refereeing through technology. While systems like VAR and Hawk-Eye have improved accuracy in many sports, debates around interpretation, game flow, and transparency reveal that these tools alone are not enough (Kolbinger & Knopp, 2020; Lago-Peñas et al., 2019).

As autonomous technologies - particularly AI - continue to evolve, their potential to take on full decision-making roles in sports invites new questions: not only about technical feasibility, but about ethical acceptability and stakeholder trust (Kolbinger & Lames, 2017; Spitz et al., 2020). These questions are especially relevant in an era where sports are both global industries and deeply cultural phenomena.

This research is motivated by the intersection of technology, ethics, and human experience. By exploring where and how autonomous refereeing could work - and whether it would be welcomed - this research hopes to contribute valuable insights for both academic inquiry and real-world implementation.

## 1.3. OBJECTIVES

The research would be to evaluate the use of autonomous referees in sports.
In order to achieve this goal, the following intermediate objectives were defined:

- To understand the feasibility and potential of implementing autonomous referees in different sports, considering their rules and nature of decision-making.
- To evaluate the potential impact of autonomous referees on the sports industry, particularly the effects on players, coaches, and spectators.

- To assess the level of acceptance of autonomous referees among key stakeholders in sports, such as athletes, coaches, and audiences.
- To analyze the ethical implications of autonomous refereeing, especially regarding decision transparency and dispute resolution processes.

## 1.4. STUDY RELEVANCE AND IMPORTANCE

Sports are an essential part of human life, with deep cultural, economic, and social significance. From the ancient Olympic Games to modern global competitions, sports have long united people across backgrounds and nations. Today, they are not only a form of entertainment but also a driver of economic activity, tourism, and social development, often reflecting and influencing societal values (Jarvie & Thornton, 2012).

In this context, the use of autonomous referees is a highly relevant and timely topic. As debates around the role of technology in sports grow, autonomous officiating systems - especially those based on artificial intelligence - raise important questions about accuracy, fairness, and trust (Makienko, 2017). These systems may fundamentally reshape how sports are played, officiated, and perceived.

This study contributes to the evolving discussion on sports technology by providing a comprehensive evaluation of autonomous refereeing. It aims to deliver actionable insights for sports organizations, athletes, coaches, and policymakers, particularly regarding stakeholder acceptance, implementation challenges, and ethical implications. Moreover, as sports are often seen as a mirror of societal values, examining the potential socio-cultural effects of removing human judgment from officiating decisions offers broader relevance.

By critically assessing both the technical and human dimensions of autonomous refereeing, this research seeks to inform responsible and effective adoption of such technologies and to support more transparent, equitable, and future-oriented developments in the world of sport.

# 2. LITERATURE REVIEW

## 2.1. INFORMATION SYSTEMS AND TECHNOLOGY MANAGEMENT

Information Systems (IS) are one of the most relevant components in the current business environment, offering significant opportunities for companies to succeed. This is because they can collect, process, distribute, and share data in an integrated and timely manner. Moreover, they help bridge geographical gaps, allowing employees to be more efficient, which in turn improves processes, administration, and information management (Gómez & Suárez, 2012). However, these advantages make organizations increasingly dependent on IS for their daily activities, necessitating greater investment in such systems (Petter, DeLone, and McLean, 2008).

A company's IS represents a combination of human and material resources responsible for processing business information, playing a significant role and being a source of competitive advantage (Ferreira & Cherobim, 2012). Information Systems use computers, equipment, databases, software, procedures, analytical models, and administrative decision-making processes (Turban, Volonino, & Wood, 2013). Traditionally, IS are designed in each functional area to support and enhance operational efficiency and effectiveness (Haag & Cummings, 2013).

Information systems consist of smaller subsystems that can function either independently or in an integrated manner. If they are capable of interrelating, they may include the IS of the entire organization. Therefore, an IS can be defined as a group of elements focused on the processing, administration, and dissemination of data and information, organized and ready for subsequent use and generated to meet an organizational need (Haag & Cummings, 2013; Turban et al., 2013).

Nowadays, companies are required to be interconnected with each other and with other organizations, because of mergers, operational cost reductions, and market strategies, among others. The need to invest in IS is indisputable, although its high cost necessitates successful implementation and integration (Lee, 2012; Pérez & Machado, 2015).

Since the 1970s, the measurement of IS success has been the subject of various studies that have allowed for the accumulation of significant knowledge on the topic (Solano et al., 2014). The key elements integral to IS are based on resource and capability theory (Ravichandran & Lertwongsatien, 2005) and are related to the software industry. An integrated focus on IS context is lacking, mainly because there is no emphasis on improving the quality of information and services (Gorla, Somers, & Wong, 2010). In this context, DeLone and McLean proposed, since 1992, a model that allowed the measurement of the impact that IS has on the organization, considering acceptance and criticisms made by researchers (Roldán & Leal, 2003).

According to Ballantine et al. (1996), Seddon (1997), and Wu and Wang (2006), the DeLone and McLean model has made several significant contributions to understanding IS success. First, it provides a diagram to classify the different success measures proposed in the literature. Second, it suggests temporal and causal interdependencies between the identified categories. Third, it provides an appropriate foundation for theoretical and empirical research due to its intelligibility and simplicity (Urbach, Smolnik & Riempp, 2009). This model is one of the most referenced in the IS literature (Gable et al., 2008; Gorla et al., 2010).

The explanation related to the effects generated by IS on organizations has led to research on assessment tools that consider organizational strategy and competitive advantage as impact variables (Bradley, Pridmore & Byrd, 2006; Gable et al., 2008).However, regardless of the focus, research on organizational benefits or positive effects becomes the business objective and a key element for the decision to invest in IS. The great "technology tree," such as computers, databases, and specifically, networks, is changing the way organizations operate and, consequently, altering their business models and structures. This work focuses on understanding contemporary thinking on this new paradigm, describing how today's companies organize the Information Technology function and representing a significant responsibility for 21st-century administrators (Askins, 2008).

Most authors contributing to this work, such as Dowling (2002) and Askins (2008), among others, offer a deep understanding of Information Technology management to help contribute to the company's success.

## 2.2. THE FOURTH INDUSTRIAL REVOLUTION

The Fourth Industrial Revolution, commonly referred to as Industry 4.0, involves merging physical assets with advanced digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), robotics, drones, autonomous vehicles, and 3D printing. These emerging technologies are frequently associated with improving efficiency, lowering costs, and maximizing profits for organizations (Mrugalska & Wyrwicka, 2017; Qin et al., 2016; Wang et al., 2016).

Within Industry 4.0, digitalization is expanded extensively across service sectors through embedded sensors integrated within manufacturing components, products, and equipment. By capturing and analyzing real-time data and combining digital information with physical production processes, these technological advancements have the potential to significantly transform industries worldwide. The rate and impact of Industry 4.0 are considered unprecedented, surpassing those of previous industrial transformations, including Industry 1.0, 2.0, and 3.0 (Mrugalska & Wyrwicka, 2017).

This contemporary shift affects all sectors of industrial production, aiming at profound transformations. Industry 4.0 was first formally introduced in 2011 at Germany’s Hannover Fair, marking a new era of industrial development and technological advancement (Qin, Liu & Grosvenor, 2016).

According to Tay et al. (2019), Industry 4.0 comprises three fundamental forms of integration:

1. Horizontal integration, which facilitates the creation of interconnected global value chains.

2. Vertical integration, enabling flexible, hierarchical connections between different layers of production systems, streamlining configuration and enhancing adaptability.

3. End-to-end engineering integration, spanning the complete value chain to support product customization.

Through these integrations, companies gain improved financial oversight and knowledge exchange across all organizational layers. Particularly with vertical integration, factories incorporate various physical and informational subsystems, such as production management tools, sensor-based monitoring, value-chain coordination, and strategic corporate planning (Wang et al., 2016). These interconnected systems enable machines to intelligently self-adjust their configurations in response to changing production requirements and product types, enhancing manufacturing flexibility (Wang et al., 2016).

Industry 4.0 represents the future landscape of manufacturing, characterized by automation, digitized factories, and intelligent, connected products. Despite being widely recognized, the academic community has not yet reached full consensus on clearly defining its boundaries and elements, complicating precise categorization. The primary characteristics of Industry 4.0 are often summarized into nine core aspects (as illustrated in Figure 2-1).

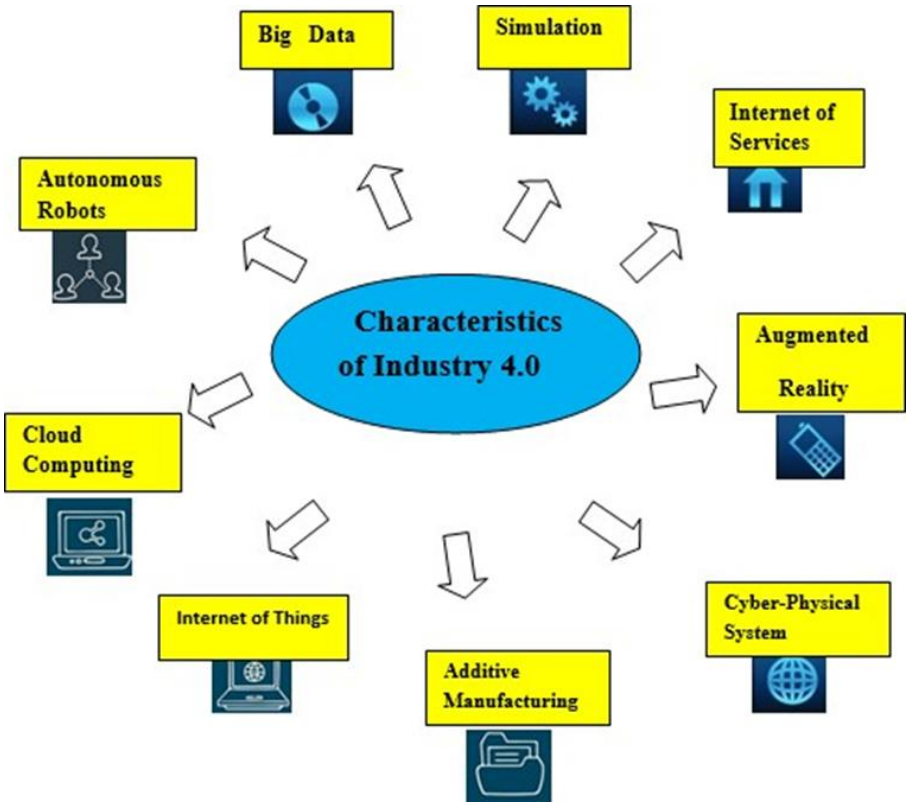


Figure 2-1 – Characteristics of Industry 4.0

Ultimately, Industry 4.0 is expected to redefine manufacturing processes by integrating new concepts into global value chains, significantly influencing the entire product life cycle. This shift includes creating innovative products, novel business models, and more responsive services. Technologies central to Industry 4.0 can anticipate product failures or performance deterioration, proactively manage service requirements, and optimize resource utilization, thus resulting in substantial cost reductions and greater efficiency (Mrugalska & Wyrwicka, 2017; Qin et al., 2016; Wang et al., 2016).

## 2.3. USE OF TECHNOLOGY IN SPORTS

Sports training involves several interconnected factors, including physical fitness, technical and tactical skills, psychological readiness, and biological preparedness for competition. Recently, advanced technologies have increasingly become essential tools to optimize athletes' training programs, helping coaches and specialists continuously track athlete performance and manage long-term health outcomes (Weldon et al., 2022). These technologies primarily analyze physiological responses, bodily functions during physical activity, and overall effects on health and sports performance.

Contemporary research indicates that perspectives regarding the integration of technology into sports training differ among athletes, coaches, and multidisciplinary support teams. Nevertheless, the strategic use of technology often positively impacts athlete performance, particularly when considering environmental factors. The effectiveness of technology integration greatly depends on how frequently it's utilized and how smoothly it can be embedded into existing training routines and programs (Mears et al., 2019).

Accurate tracking and management of training loads can significantly benefit both athletes and coaching staff. To achieve maximum benefit, training monitoring systems should be user-friendly, offering straightforward yet scientifically rigorous data analysis and actionable reporting (Heishman et al., 2020). Researchers have observed meaningful relationships and predictive strengths among various monitoring platforms, though each type may provide distinct data beneficial for professional-level understanding and training customization (Luteberget et al., 2020).

Claudino et al. (2019) highlight that data-driven approaches enhance athlete development, both through short-term training interventions and sustained long-term planning. Research has predominantly focused on technological applications within team sports like football, basketball, handball, and volleyball, emphasizing the role of technology in streamlining training processes and enhancing performance outcomes. Additionally, innovations in sports technology continuously contribute to improved equipment, training methodologies, and athletic performance (Yu, 2022).

Bădescu et al. (2022) conducted research examining the role of technological devices and systems in both training and competitive sports environments. Their findings offer valuable insights to sports organizations, coaching staff, and sports authorities about how technology can effectively support athletic performance. They concluded that coaches and training specialists typically tailor technological tools and training interventions to match the individual

characteristics of athletes. Moreover, major sports clubs have emerged as influential players in advancing knowledge on athlete monitoring, training optimization, recovery strategies, injury prevention, and overall sports performance enhancement.

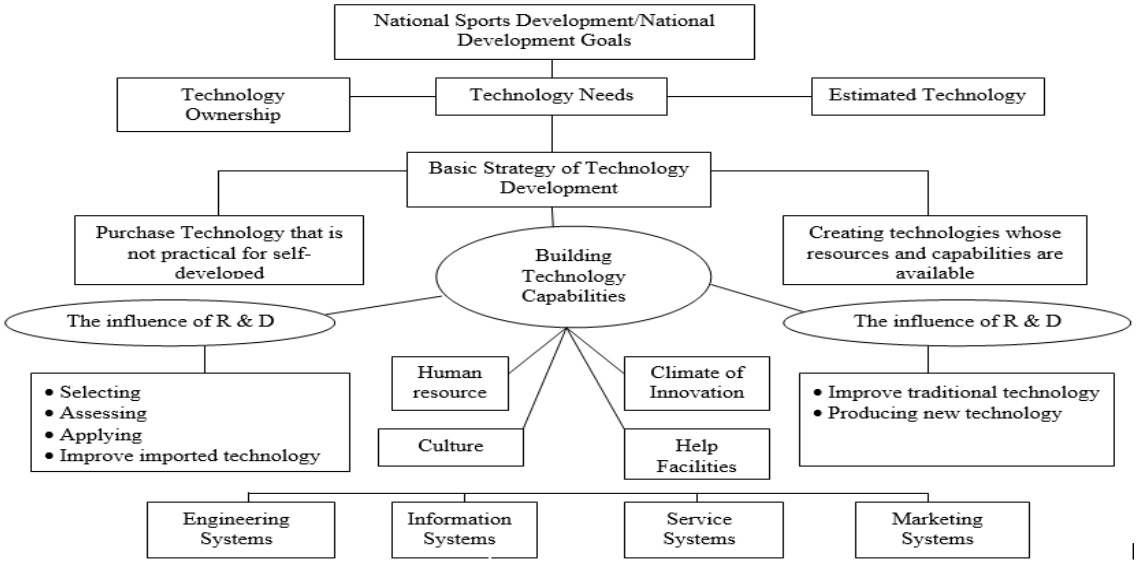


Figure 2-2 - Technology Development Process in Sports (Kristiyanto et al., 2019)

Technology is becoming increasingly influential in sports, with researchers and engineers continuously using improved design methods and advanced materials to boost athletic performance. These innovations not only influence sports equipment but also significantly impact the effectiveness of athlete training programs (Sherwood & Drane, 2015).

For instance, one widely adopted technological approach in sports training is video analysis, commonly employed to study tactical behaviors and team strategies both during training sessions and in preparation for competition (Viduka et al., 2021). While methods for systematically categorizing video content into clear tactical patterns are still evolving, current analytical approaches typically focus on monitoring player movements, behavior patterns, and even refereeing decisions to enhance overall match understanding and performance outcomes.

## 2.4. TECHNOLOGY IN REFEREEING

Technological evolution in the 21st century has changed the way people communicate and interact with each other, and consequently, has also affected how disputes are managed and resolved. Arbitration is a flexible and innovative process that has often adopted the use of technology when it has been impossible to conduct hearings in person (Blake et al., 2016).

In recent years, researchers have increasingly investigated how training methodologies and strategic planning contribute to football team performance. Alongside these developments, the role of referees has drawn greater attention, especially in maintaining fairness and consistency throughout matches (Andrade et al., 2021; Pietro & Mazzeo, 2019). Due to the

complexity of football and the rapid pace of play, referees and their assistants must make swift, accurate decisions in high-pressure environments (Kolbinger & Lames, 2017).

To minimize human error and support decision-making, football has progressively integrated various technological systems (Spitz et al., 2020; Tamir & Bar-Eli, 2021). One of the most significant is the Video Assistant Referee (VAR), first implemented by FIFA during the 2018 World Cup in Russia. VAR is applied in specific scenarios such as goals, penalties, red cards, and mistaken identity cases (FIFA, 2019). The process involves either the referee requesting a review or receiving a prompt from VAR officials, who communicate via headset. The referee then consults the video footage on the sideline before making a final decision (FIFA, 2019).

Over the years, various types of data have become available for sports data analysis. Specifically, the prevalence of play-by-play data (Pappalardo et al., 2019), as well as research data, has allowed for new analyses in football that were previously impossible (Gudmundsson & Horton, 2017). Some typical examples include the analysis of ball-passing networks, formation analysis, and space evaluation (Spearman, 2018).

## 2.5. CONCEPT AND RELEVANT CHARACTERISTICS OF ARBITRATION

Online arbitration is distinct from traditional arbitration. The common belief that online arbitration is merely a combination of online and traditional mechanisms may not reflect reality. According to some authors, the difference in this type of online arbitration lies in its defining elements. Arbitration elements often vary across different legal systems, making it difficult to provide a strict and singular definition applicable everywhere (Born, 2009). The necessary characteristics to be a football referee or arbiter are:


Figure 2-3 - Necessary Characteristics to be a Football Referee

A sports referee represents the official entity that regulates the sporting behavior of the game's participants and ensures the rules of the game are followed. Effective game management requires the referee to perceive plays for correct decision-making (Rebelo et al., 2002). In this sense, the referee must act firmly and always maintain a discreet attitude.

According to the International Football Association Board (2013), the main duty of a football referee is to ensure the Laws of the Game are applied. The positioning of the referee with the

ball during the game is provided in the guideline section for referees in the rulebook (IFAB, 2013). The main recommendations are:

- The game should unfold between the referee and the closest Assistant Referee (AA) to the play.
- The closest AA should be within the referee's field of vision, and the latter should use the diagonal system.
- Follow the game from a lateral position.
- Be close enough to observe the game without interfering.

"What needs to be seen" does not always happen near the ball. Therefore, the referee must pay attention to aggressive individual confrontations between players away from the ball, possible infractions in the area where the game is heading, and infractions committed after the ball has been moved away.

The study by Oliveira et al. (2011) described some factors related to correct decisions made by the arbitration team. The referee's vision and ability to interpret quick plays, simultaneous and sequential movements, are factors that depend on vision.

Over the years, football has been recognized as the world's most popular sport. Attention given to players and coaches seems to increase, highlighting the role played by referees in the game and the acknowledgment that their task is complex (Gulec & Yilmaz, 2016). Many studies aim to understand how referee performance is affected by factors like activity profiles, total distance covered, running speed, accelerations, and physical capacity (Johansen, 2015). On the other hand, literature on football referees lacks research on topics like conflict management, recruitment and retention, body composition, injuries, and the refereeing team (Samuel et al., 2015; Casajús et al., 2016). Therefore, it's essential to understand the themes associated with football arbitration from a broader perspective, as it's a complex topic, as described by Aragão et al. (2018) in their integrative review.

Vasilica et al. (2022) conducted a systematic literature review aiming to identify studies about referees and football referees. The authors concluded that research on football referees is still growing, largely because it's a profession that only professionalized in the last decade and only in some countries compared to player and coach careers. However, it's now a fundamental area, confirmed by the increasing attention researchers have given to the topic, producing more impactful investigations in this knowledge domain.

Referees in football hold significant influence over match outcomes through decisions involving goals, penalties, issuing yellow or red cards, calling offsides, and identifying fouls. When referees display biased behavior, intentionally or unintentionally, the integrity and fairness of the sport can be questioned. Persistent bias may lead fans to perceive competitions as unfair, ultimately harming the sport's popularity and causing financial implications for leagues due to decreased viewership and revenue (Dohmen & Sauermann, 2016).

Various economic studies have identified patterns of bias across sports competitions. Dohmen and Sauermann (2016) reviewed several studies highlighting such biases. For instance, Duggan & Levitt (2002) identified signs of match manipulation within professional wrestling. Similarly, research by Garicano et al. (2005) examined referee bias in Spain's La Liga, while Sutter & Kocher (2004) analyzed bias in Germany's Bundesliga. Additionally, Lucey & Power (2009) found evidence of referee bias related to stoppage time added at the end of regular matches in both the Major League Soccer (MLS) in the United States and Italy's Serie A.

## 2.6. THE USE OF ARBITRATION IN THE DIGITAL AGE – THE VAR SYSTEM

The VAR system was initially tested by several national federations, such as Italy's Serie A and Germany's Bundesliga (Kolbinger, 2020). An analysis based on the initial trials of 804 games concluded that in most games, there was no review and in every three games, there was a clear and obvious error by the referee (Simon, 2020). In this sense, the VAR system improved the overall accuracy in major game decisions from 93% to 98.9%. Furthermore, in about 8% of all games, VAR had a decisive impact on the match outcome (IFAB, 2018).

The concept of career change in sports psychology is often framed by theoretical models that map out the typical stages athletes experience throughout their professional evolution (Samuel et al., 2017). While the introduction of VAR marked a major step in football technology, it wasn't the first. Prior to VAR, goal-line technology was one of the earliest tools adopted to support referees, ensuring the ball had fully crossed the line before awarding a goal.

The Australian league was the first to implement VAR on a league-wide scale, reflecting a broader shift toward technological integration in modern football. Soon after, FIFA officially sanctioned the use of VAR in all matches, and it has since become standard in major leagues like the EPL, Bundesliga, La Liga, Serie A, and Ligue 1 (Spitz et al., 2020). Its primary aim is to assist referees in making accurate decisions in critical match situations.

Despite its growing presence, VAR has not been universally embraced. Critics argue that the system disrupts the natural rhythm of the game and slows down play, leading to frustration among players and fans (Kolbinger & Knopp, 2020). During the 2018 FIFA World Cup, concerns were even raised about potential bias in VAR decisions favoring European teams.

As a relatively recent innovation, the long-term impact of VAR on the game remains under evaluation. Early research has begun to assess its effectiveness. For example, Lago-Peñas (2019) highlighted changes in match dynamics, while Han et al. (2020), in a study of the Chinese Super League, observed fewer fouls and offsides in matches using VAR. They also noted that added time increased post-implementation, along with a rise in goals and penalties.

## 2.7. Legitimacy, Efficacy, and Efficiency of Technologies Available to Arbitration

Sport is recognized globally as an influential activity that engages diverse sectors, revolving around physical competition structured by defined rules and emphasizing values such as morality and personal character (Lopes, 2019). Over time, athletes have continually pushed the boundaries of athletic performance. Technology has greatly supported these advancements by enhancing sports equipment, refining training methods, and optimizing athletic preparation processes (Hoye & Parente, 2016).

Appropriately applied technology can greatly improve the efficiency and effectiveness of observational techniques and analytical assessments in sports. Current technological advancements eliminate the need for excessively slow or complicated data-processing methods, making the process quicker and simpler (Valente, 2018). Fowler (2013) identifies cost, user-friendliness, and reliability as the three primary factors determining the widespread adoption of technological innovations. Moreover, integrating technology into sports significantly reduces errors in refereeing by providing objective, accurate data on player actions (Spitz et al., 2020; Kolbinger & Lames, 2017).

Technological tools like VAR support referees' decision-making processes, enhancing overall accuracy. However, various contextual factors, such as a team's reputation or playing style, may still unintentionally influence referees' judgments (Spitz et al., 2016). VAR becomes particularly beneficial in situations where referees might experience decision-making errors due to challenges in perception, information processing, or rapid judgment calls (Kolbinger & Lames, 2017).

Despite these benefits, uncertainty remains regarding the extent to which video replays assist referees in subjective decisions requiring rule interpretation (Helsen et al., 2019). Previous research suggests that referees gain clearer insights and improved decision-making from video replays, particularly with slow-motion playback and multiple camera angles (Pizzera et al., 2016; Spitz et al., 2017).

One critical decision referees must regularly make is determining offsides, as these calls can significantly influence the final outcome of a match. Several studies have confirmed that implementing VAR reduces the frequency of incorrect offside calls (Lago-Peñas et al., 2019, 2020; Han et al., 2020). According to Kubavi et al. (2022), VAR corrects these errors by mitigating the "flash-lag effect," an optical illusion where referees mistakenly perceive moving players as being further ahead than they truly are.

## 2.8. Referee Decision Making in Sport through the Application of VAR Technology

Referees regularly experience considerable physical and psychological stress due to various game-related responsibilities, including decision-making, communication with athletes and teams, match management, crowd interactions, and overall pressure (Pietraszewski et al., 2014). Beyond physical conditioning, psychological readiness and practical experience significantly influence referees' ability to perform effectively (Spencer, 2015).

Mistakes during matches and external pressures from players, coaching staff, or spectators can create high levels of stress and anxiety, diminish confidence, and sometimes even lead referees to leave the profession (Karaçam & Pulur, 2017). Prior research has emphasized the concept of self-efficacy, defined by Bandura as the belief in one's capability to successfully perform a specific task, as an essential determinant of referees' performance, behaviors, satisfaction, and overall stress management (Guillén & Feltz, 2011).

Another critical factor, referees' knowledge of the game, includes their confidence in understanding the rules and tactical aspects of the sport (Arslanoğlu et al., 2018). Although theoretical knowledge and preparation are foundational, the practical application of rules during real-time match scenarios remains paramount for refereeing effectiveness.

On the other hand, Kolbinger and Knopp (2020) noted that VAR implementation negatively influenced spectator emotions within Premier League matches. To address this, football governing bodies might consider enhancing transparency in the VAR process, such as openly broadcasting discussions between referees and video assistants or employing technologies that clearly communicate the decision-review process directly to spectators within the stadium (Stoney & Fletcher, 2021).

Research by Lago-Peñas et al. (2019) analyzing the broader impacts of VAR suggested that VAR doesn't fundamentally alter the dynamics of elite-level football but does lead to a reduction in offsides, fouls, and yellow cards, alongside an increase in additional time at the end of the first half. Nevertheless, the evidence remains inconclusive regarding whether VAR enhances decision-making accuracy or fully achieves its intended purpose of improving fairness (Kolbinger & Link, 2016; Kolbinger & Lames, 2017). Given that VAR immediately reviews crucial referee decisions, one might expect certain impacts: (i) fewer decisions reviewed by VAR will favor home teams after VAR introduction, and (ii) decisions concerning penalties, red cards, and even match added-time allocation—despite added-time not being directly reviewed—should theoretically become more impartial and fair for both teams (Kolbinger & Lames, 2017).

## 2.9. THE USE OF AUTONOMOUS REFEREES AND THE APPLICATION OF AI IN SPORTS

The implications of technological developments and innovations for humans are increasingly complex, with machines shifting from being useful tools for production to playing a critical role in various spheres of organizational and economic life (Coupê, 2019; Arslan et al., 2021).

Modern society's work, driven by digitization and predominant communication technology, includes uninterrupted connectivity, immediacy, and a high set of challenges (Derks et al., 2015). In this sense, professional life and jobs are being transformed and reconfigured according to the prevalence of the emerging digital economy and emerging technologies, such as big data, machine learning, and artificial intelligence (AI) (Petriglieri et al., 2019).

Recent studies provide ample evidence of various ways managers and workers operate in a complex environment characterized by rapid digital interactions, technological intensity, and the gig economy (Derks et al., 2015; Petriglieri et al., 2019), thus representing a perfect technological storm. In this context, a Forbes article (2019) suggested a vital role for modern technologies in human resource functions.

AI is a crucial and fundamentally transformative new technology that can be defined in various ways. Generally, it corresponds to a machine-based system's ability to correctly interpret external data, learn from it, utilize its flexibility, and adapt knowledge to achieve specific goals and perform tasks (Kaplan and Haenlein, 2019).

Artificial intelligence (AI) research typically falls into four primary areas. The first focuses on neural networks and connectionist models, exploring how machines can identify patterns and learn over time. A second branch draws from molecular biology and seeks to simulate artificial life. A third area, closely related to robotics and inspired by biological systems, aims to develop machines that replicate life-like behaviors. The fourth, more classical branch of AI, has historical ties to disciplines such as psychology, epistemology, and sociology, and is primarily concerned with replicating human reasoning and cognition within machines (Petriglieri et al., 2019).

As AI technologies evolve, they are expected to give rise to machines with vastly improved capabilities compared to today’s systems. For instance, speech recognition tools are projected to reach levels where they can naturally engage in conversations using unstructured spoken and written language. In healthcare, AI-driven expert systems hold the potential to enhance both clinical decision-making and administrative processes, improving patient outcomes and resource distribution (Kaplan & Haenlein, 2019).

Nonetheless, the possibility of AI surpassing human intelligence remains uncertain. There is no consensus on whether such advancement is achievable, or how long it would take. Future AI is expected to include cognitive traits like learning, reasoning, and perception. Currently, most applications fall under “narrow AI,” which handles specific tasks. However, ongoing

research is exploring the shift toward general AI — systems capable of independently solving new, unfamiliar problems by applying reasoning and planning skills beyond their original programming (Kaplan & Haenlein, 2019).

Football has an electronic generator that can inform the referee of a penalty in time. The so-called "electronic football referee" refers to the system of timely judgment of goal occurrences and offside phenomena in football games. Still, in sports like football, boundary violations often occur. The very fast ball makes it difficult to visually determine if the ball's pressure point is in contact with the sideline, which is controversial for the best judgment (Spitz et al., 2020; Kolbinger & Lames, 2017). The real-time three-dimensional motion capture optical device can continuously capture the real-time movement sphere's digital precision information, and the machine calculates the sphere center's three-dimensional coordinates.

Until the current management of Artificial Intelligence, many institutions and organizations have had the opportunity to benefit from development in areas such as Total Quality, database management, customer relationship management, digital management, etc. However, today's Artificial Intelligence studies promise a shift to a new management model, incorporating the advantages of previous management styles. This new artificial intelligence provides technology for analysis, reporting, and automation, storing data obtained from many interrelated or unrelated elements in an ecosystem (Kaplan & Haenlein, 2019). Nevertheless, thinking about the future of sports in light of the AI fields and provided developments makes us feel that this will be an era of developments with much deeper horizons. According to Senaar (2019), the applications of artificial intelligence used in today's sports world are divided into four main categories: chatbots, computer vision, automatic journalism, and wearable technology.

Referees benefit from some technological developments. Errors can occur, especially in sports with large spectator counts, such as football, basketball, and tennis, where they face immense pressure. Currently, efforts are being made to minimize referee errors with applications like the "VAR" system in football. Artificial intelligence can make a significant contribution in this field. Today, refereeing is based primarily on human perception. In the near future, information on the playing field is expected to be presented by analyzing data from dozens of sensors covering the competition area, making it more accurate. Initially, AI will be a good assistant for referees, but it will not be surprising to see refereeing entirely performed by artificial intelligence in the future (Barlow & Sriskandarajah, 2019).

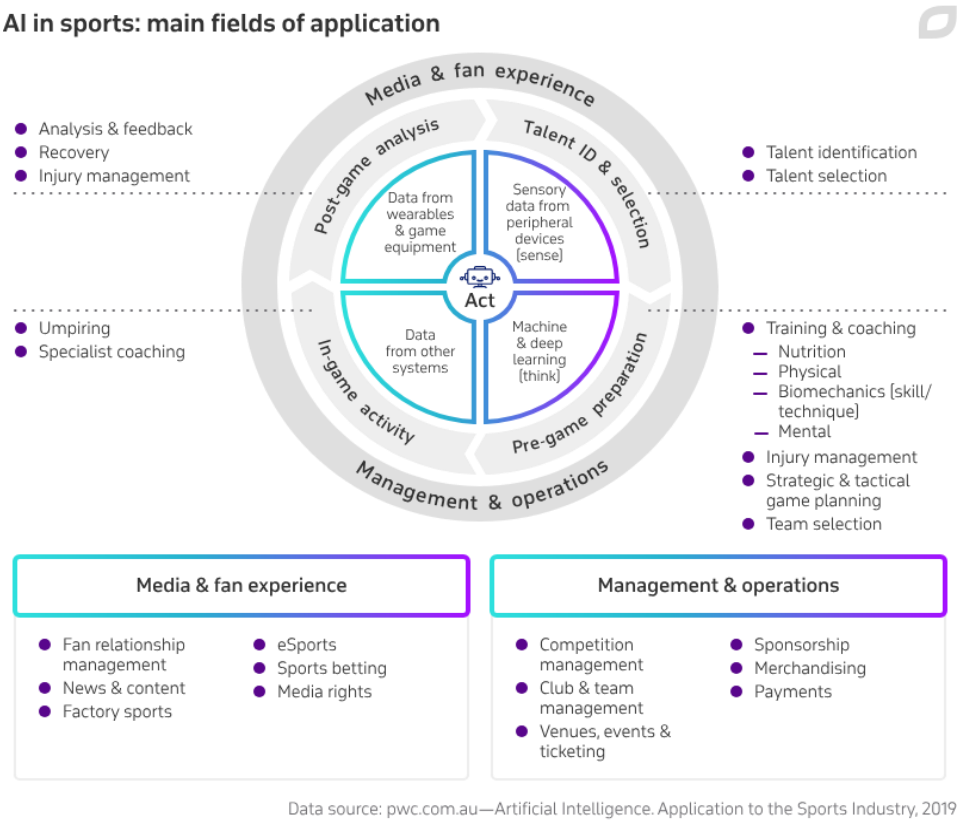


Figure 2-4 - AI Technology Structure for the Sports Industry (Source: ATASOY et al., 2021)

# 3. METHODOLOGY

This study utilizes a quantitative, cross-sectional survey design to explore perceptions surrounding the use of autonomous referees in sports. By capturing data at a single point in time, this approach facilitates an in-depth examination of how various stakeholders (including players, coaches, referees, and spectators) view and evaluate the feasibility, fairness, and ethical implications of fully automated officiating systems.

## 3.1. RESEARCH DESIGN

The main goal of the survey design is to gather quantifiable information about respondents' opinions regarding AI-driven refereeing. The study specifically aims to understand the degree of support or opposition to the use of autonomous referees, the advantages or disadvantages of this technology, and the potential influence of varying positions in sports on these viewpoints. A survey-based methodology was chosen since it was efficient in obtaining a large amount of quantitative data in a short amount of time.

## 3.2. SURVEY INSTRUMENT

A Google Forms survey was used to collect data. An informed consent statement at the beginning of the survey made sure that everyone included understood the nature and goal of the study, the confidentiality procedures, and their right to discontinue participation at any moment. After agreement, a topical introduction was given outlining the purpose of the study of autonomous referees and how the research would be informed by their answers. Age group, principal function in sports (player, coach, referee, spectator), years of experience, and knowledge with sports technologies were among the demographic and background data gathered by the first set of items. To enable the findings to be broken down by responder profile, these questions were either multiple-choice or short answer in nature.

Likert-scale items (with 1 denoting strongly disagree and 5 denoting strongly agree) were used in the following sections to measure attitudes in important theme areas. One set of questions measured respondents' comfort levels with automated officiating and addressed technology adoption. To determine whether stakeholders thought an AI-based referee could lessen human bias or the conventional, human part of sport, another series of questions examined perceived effects on fairness, game flow, and emotional engagement.

Particular attention was paid to practical and ethical issues, such as whether participants believed greater transparency was required when utilizing AI and whether contested calls should have an appeals mechanism. At the conclusion, extra questions evaluated the viability and prospects of autonomous referees in different sports and asked if respondents preferred gradual or quick adoption.

Lastly, open-ended questions were added to help capture personal stories or subtle issues that a Likert-scale approach would overlook. Participants might talk about ethical concerns,

specify which sports they believe would benefit most from autonomous referees, or express their opinions on how AI refereeing might change the viewing experience. The questionnaire was pilot tested by a small group of coworkers before being made widely available. They provided input on the questionnaire's instructions, question structure, and Likert-scale items' usability. The language and sequence of the questions were slightly changed because of their recommendations.

## 3.3. SAMPLING AND DATA COLLECTION

Data were collected using a convenience-snowball sampling approach. The Google Forms link was initially shared among friends, family, and coworkers, who were then encouraged to forward it to anyone with an interest in sports or technology. This informal network-based recruitment was supplemented by posts on social media platforms, where the survey link was made publicly available to further diversify the sample.

In addition, efforts were made to target referees specifically by sending the questionnaire to relevant contacts within the “Associação de Futebol” de Lisboa and the “Associação de Futebol do Porto”. This outreach aimed to secure input from referees currently involved in traditional officiating, providing valuable insights into whether (and how) AI-based refereeing might integrate into established officiating structures.

During the two-to-four-week data-collection window, periodic reminders were posted or circulated to encourage participation. No personal identifiers (such as names or emails) were required in the survey, and anonymity was assured to minimize social bias and encourage honest responses.

## 3.4. DATA ANALYSIS

Survey responses were exported from Google Forms into statistical software for analysis. Descriptive statistics (mean, standard deviation, frequency) were calculated to summarize responses. Given the ordinal nature of Likert-scale data, non-parametric inferential methods were employed:

Spearman’s rank correlation was used to assess monotonic relationships between key variables (e.g., trust and comfort with autonomous referees, fairness perception and acceptance).

The Kruskal-Wallis H-test was applied to compare comfort levels across groups based on sport type and demographic factors.

Additionally, association rule mining (using the Apriori algorithm in Python’s mlxtend library) was conducted on binarized Likert responses. This analysis uncovered recurring belief patterns, such as the link between trust and perceived fairness, and support for gradual implementation.

Finally, qualitative responses to open-ended questions were analyzed thematically to identify concerns and motivations not captured by structured survey items.

## 3.5. Ethical Considerations

At the start of the survey, all participants were given informed consent guidelines that explained the precise goals of the research project, the voluntary nature of their participation, and the confidentiality of their answers. No personal identifiers, including names or email addresses, were gathered, and respondents were free to leave the questionnaire at any time. The dataset is safely kept and will only be utilized for study, guaranteeing that confidentiality requirements are met in compliance with academic norms.

## 3.6. Limitations

Convenience sampling inside a particular organization was used for data collection, hence the final sample may not accurately reflect the global community of sports stakeholders. Due to their personal interests or professional positions, certain employees may be more positive or more negative about sports technology, which could lead to bias. Furthermore, the study's cross-sectional design makes it impossible to investigate how perceptions might change over time or in reaction to new developments in artificial intelligence or sports technology.

## 3.7. Expected Outcomes

This study attempts to provide thorough insights into how different sports stakeholders respond to and interact with the concept of completely autonomous referees by combining quantitative and qualitative data. The analysis will show if participants believe that this technology is a positive move that will improve game integrity and fairness, or if there are still unsolved ethical, practical, or cultural issues that could prevent widespread use.

## 3.8. CURRENT STAKEHOLDER PERCEPTIONS OF AUTONOMOUS REFEREES

Following the data collection procedures detailed in the Methodology chapter, this section presents the survey instrument used to assess stakeholder perceptions regarding the use of autonomous referees in sports. The aim was to capture a comprehensive understanding of how players, coaches, referees, and spectators perceive the feasibility, fairness, and ethical implications of fully automated officiating systems.

The questionnaire was designed to address the following areas:

Respondent characterization: This section gathered demographic and background information, such as age, primary role in sports, years of involvement, and familiarity with sports technology. This data allowed for profiling responses across different stakeholder groups.

Comfort and acceptance of autonomous refereeing: A series of Likert-scale questions assessed respondents' comfort levels with replacing human referees with autonomous systems and their general attitudes toward technology-driven decision-making.

Perceived fairness and bias reduction: Questions in this section explored whether stakeholders believe autonomous referees could enhance fairness by minimizing human errors and reducing susceptibility to external pressures.

Impact on game experience and emotional engagement: Items here examined how respondents felt autonomous refereeing might influence the excitement, suspense, and overall enjoyment of sporting events.

Ethical and practical concerns: This part addressed issues such as accountability for incorrect decisions, the importance of transparency, and the perceived need for appeal mechanisms in fully automated systems.

Adoption preferences: Finally, respondents were asked about their support for gradual versus immediate implementation and their views on which sports might be best suited for autonomous referees.

Additionally, open-ended questions were included to capture nuanced opinions and concerns that might not be fully expressed through structured items. These qualitative responses provided deeper insights into stakeholder attitudes toward this emerging technology

# 4. STUDY ON STAKEHOLDER PERCEPTIONS: ANALYSIS AND DISCUSSION

## 4.1. CURRENT STAKEHOLDER PERCEPTIONS OF AUTONOMOUS REFEREES

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Additionally, open-ended questions were included to capture nuanced opinions and concerns that might not be fully expressed through structured items. These qualitative responses provided deeper insights into stakeholder attitudes toward this emerging technology.

## 4.2. RESPONDENT CHARACTERIZATION

The survey attracted 146 participants. These include people with an interest in or who are attracted to sports, such as players, coaches, and spectators. Thus, they were individuals with experience in sports with human referees and the recently introduced autonomous referees. Therefore, they would resent valuable information regarding how autonomous referees fare and their opinions about them in terms of reliability, decision-making, real-time information, bias, and subjectivity.

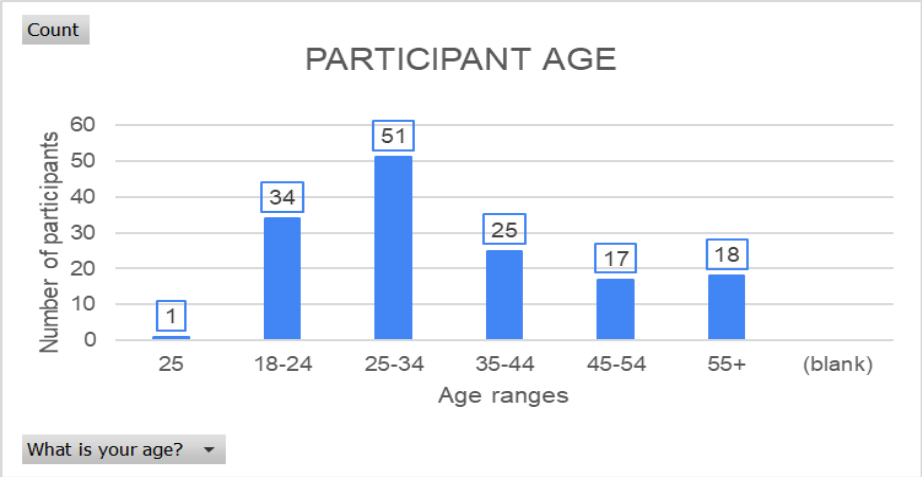



Figure 4-1 – Participant Age

The distribution of respondents by age group is illustrated in Figure 4-1. As shown, the most populous age group was 25–34, comprising 51 individuals out of the total 146 participants. This was followed by the 18–24 age group, with 34 respondents. There were 25 individuals in the 35–44 category, which also included participants who specifically reported being 25 years old. The 45–54 age group constituted 17 participants, while 18 respondents were aged 55 and older. These results indicate a clear dominance of young adults (ages 18–34) among the surveyed stakeholders.

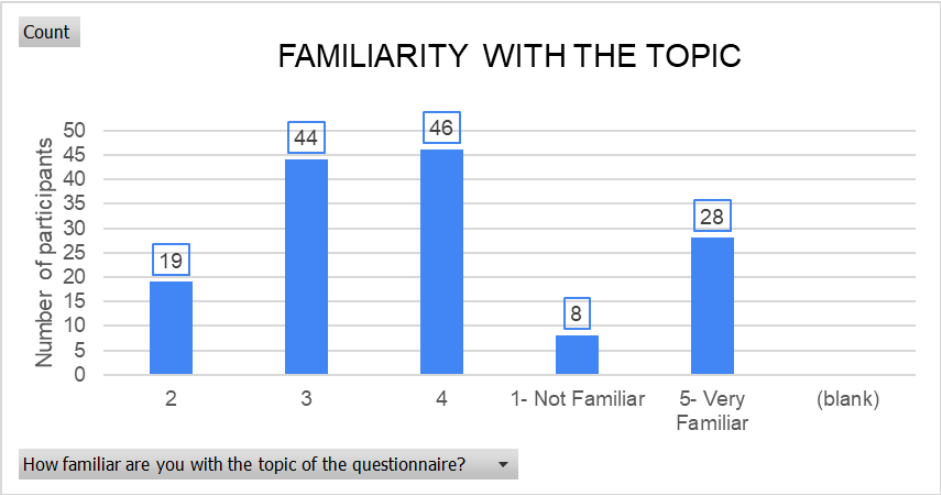



Figure 4-2 - Familiarity with the topic

Respondents' familiarity with the topic is summarized in Figure 4-2. The data reveal differing levels of awareness among participants: most reported being somewhat familiar (46) or moderately familiar (44), indicating a solid foundational knowledge. Additionally, 28 respondents described themselves as very familiar, suggesting expertise or detailed understanding of the subject. In contrast, 19 participants were only slightly familiar, and eight indicated they were unfamiliar. These findings highlight a heterogeneous distribution of familiarity, with the majority demonstrating at least moderate awareness, which supports the reliability of their responses to the questionnaire.

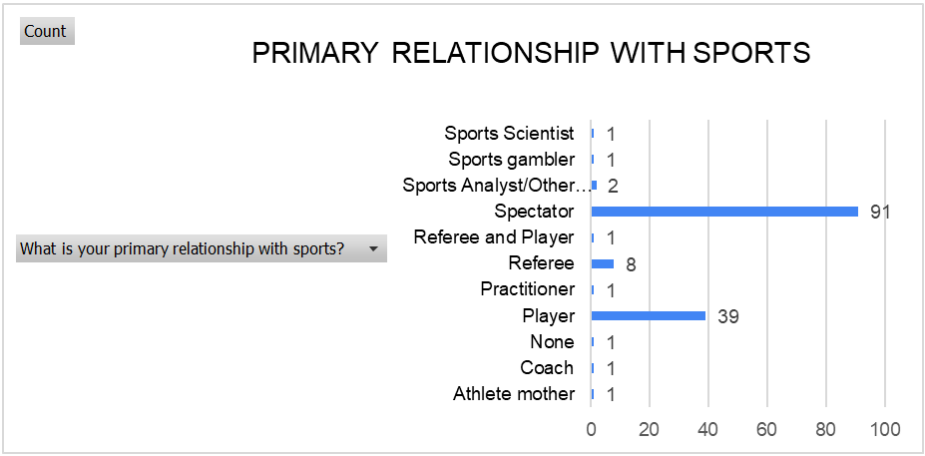



Figure 4-3 - Primary relationship with sports

The participants' primary relationship with sports is shown in Figure 4-3. As illustrated, the majority identified themselves as spectators (91 out of 146), indicating a strong interest in watching rather than directly participating. Players formed the second-largest group, with 39 respondents reporting active involvement in sports. Notably, eight respondents were referees, underscoring the presence of officiating roles within the sample. Other individual roles included athlete mothers, coaches, practitioners, sports gamblers, sports scientists, and those who combined roles such as player and referee. Additionally, two participants identified

as sports analysts or other professionals, reflecting diverse professional engagements in the sports sector.

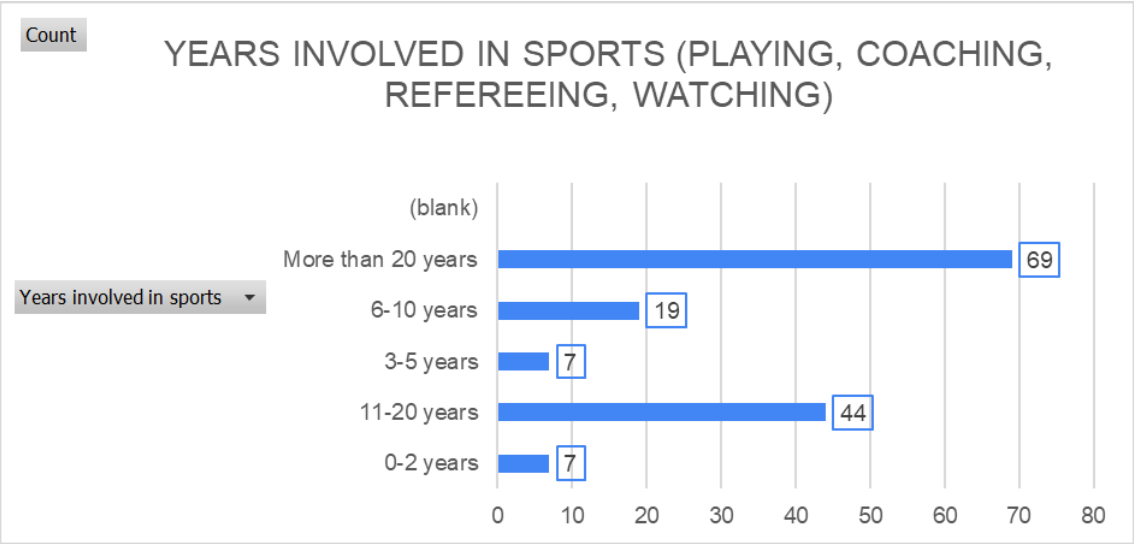



Figure 4-4 - Years involved in sports

Participants' years of involvement in sports are summarized in Figure 4-4. Most respondents (69) reported over 20 years of experience, indicating a strong, long-term connection to sports. Another 44 had between 11–20 years, while 19 fell into the 6–10 years range. Shorter-term involvement was evenly split, with seven each reporting 0–2 and 3–5 years. These results highlight a clear predominance of long-standing engagement in sports.

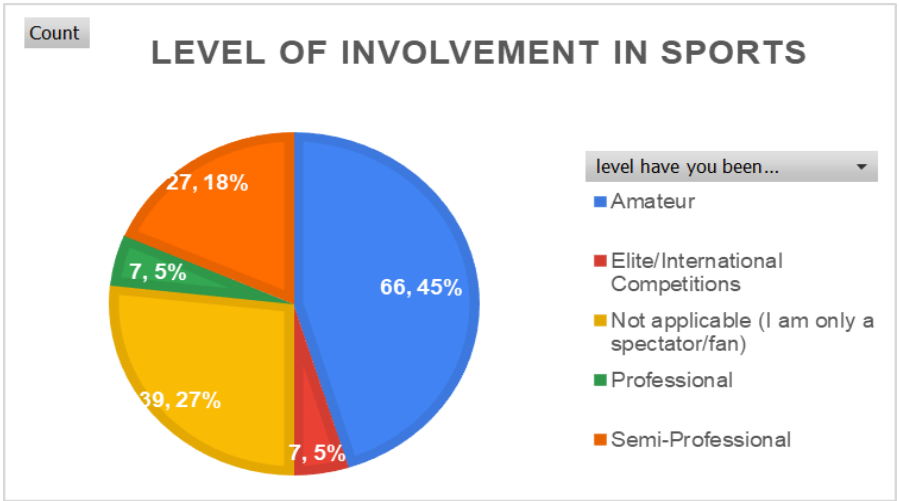



Figure 4-5 - Involvement in Sports

Figure 4-5 illustrates the varied levels of sports participation among respondents. Most (66,45%) reported amateur involvement, reflecting widespread recreational engagement. Semi-professionals accounted for 27 participants, while seven each identified as professional or elite athletes, indicating familiarity with high-level competition. Additionally, 39 described

themselves solely as spectators, showing strong interest without direct participation. Overall, the data highlights a broad range of involvement, heavily skewed toward amateur activity.

## 4.3. DESCRIPTIVE ANALYSIS

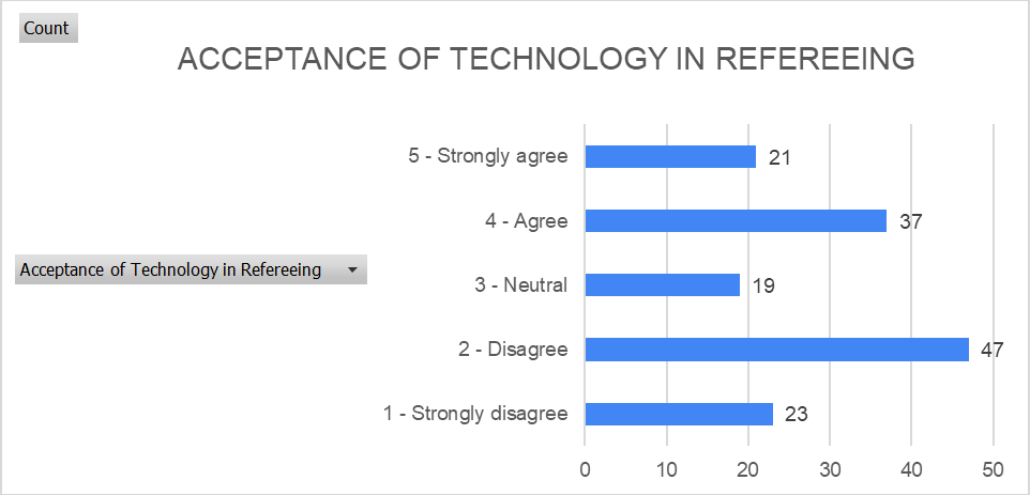



Figure 4-6 – Comfort with the Idea of Fully Autonomous Referees

The distribution of responses regarding comfort with the idea of fully autonomous referees is presented in Figure 4-6. There was a mixed perception about refereeing decisions being entirely made by technology. Forty-seven respondents were in opposition, exhibiting doubt or resistance to adopting such technology. Thirty-seven agreed, supporting the idea that technology could enhance refereeing accuracy. Nineteen respondents were neutral, demonstrating ambivalence or uncertainty. Strong agreement was indicated by 21 respondents, showing they believed technology positively impacts officiating, while 23 strongly disagreed, reflecting firm opposition. Overall, feelings were divided, with large numbers both for and against the use of technology in refereeing sports.

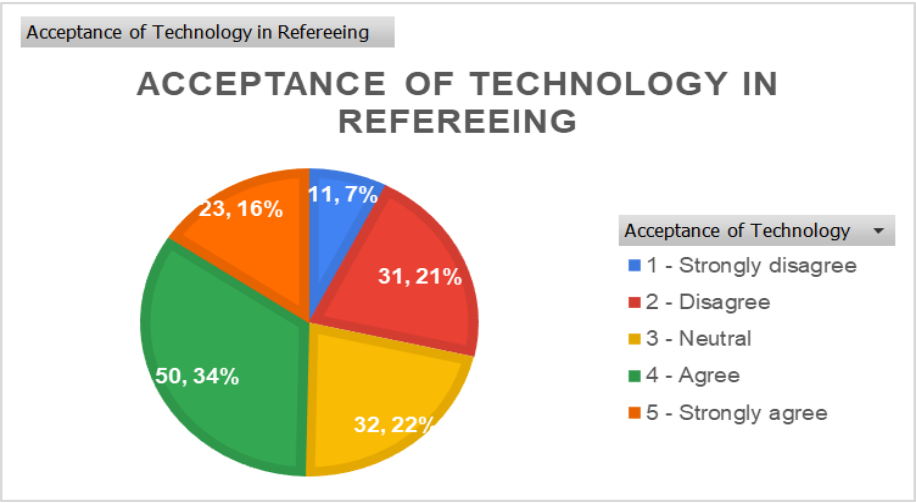



Figure 4-7 – Trust in Autonomous Referees doing in-game decisions

The varying levels of trust in autonomous referees making in-game decisions are illustrated in Figure 4-7. Similarly to earlier findings, the survey shows contrasting opinions about relying on a standalone system to make calls such as fouls or offsides. The largest group, with 50 responses (34%), agreed with its use, indicating strong support for technology in officiating. Thirty-two respondents (22%) were neutral, reflecting uncertainty or ambivalence. Thirty-one disagreed, suggesting some resistance, while 23 strongly agreed, showing firm confidence in technology. Eleven strongly disagreed, highlighting significant opposition. Overall, opinions were polarized, though there is a noticeable trend toward acceptance among many respondents.

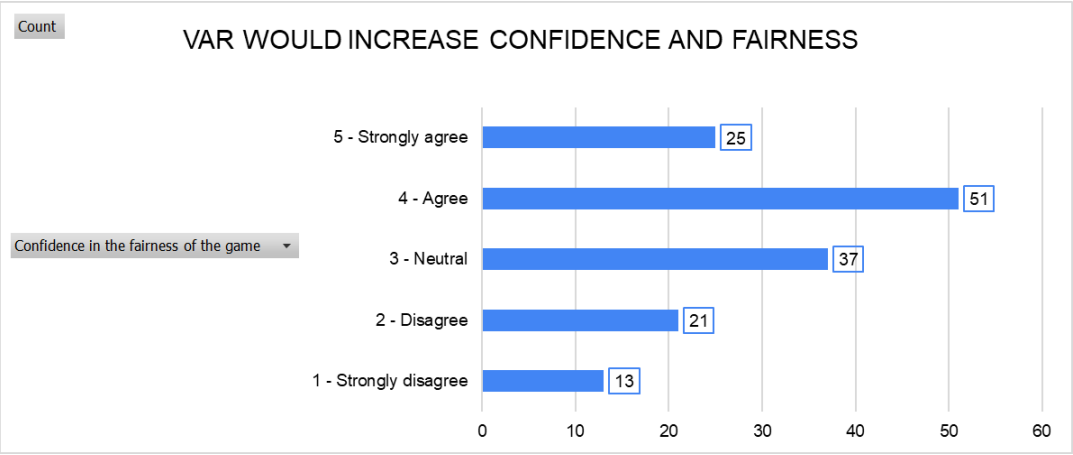



Figure 4-8- VAR would increase confidence and fairness

The perceptions of whether VAR would increase confidence and fairness in the game are presented in **Figure 4-8**. Regarding confidence in the integrity of the sport, the majority of respondents (51) agreed that games are generally fair, indicating a positive view of fairness in sports. Thirty-seven gave neutral answers, reflecting indecision or uncertainty. The fewest, 25, strongly agreed and firmly believed in the integrity of games. Meanwhile, 21 disagreed on the grounds of fairness, and 13 strongly disagreed, showing considerable skepticism. Overall, the findings suggest a general trust in fairness, although substantial reservations persist among about half of the respondents.

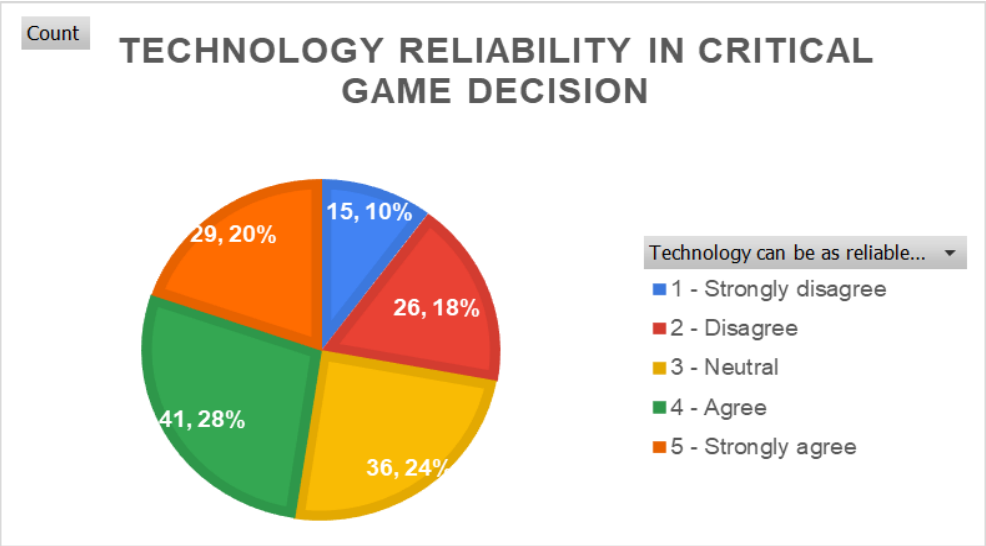



Figure 4-9 - Technology reliability

The respondents' views on the reliability of technology compared to human referees are depicted in Figure 4-9. The data show mixed reactions: 41 participants (28%) agreed that technology is as reliable as human judgment, indicating strong faith in its performance. Thirty-six were neutral, suggesting doubt or ambiguity, while 29 strongly agreed, demonstrating belief in technology's potential. Conversely, 26 participants disagreed and 15 strongly disagreed (10%), highlighting persistent doubts about technology equaling human refereeing. In conclusion, although there is considerable support for technology, significant concerns remain.

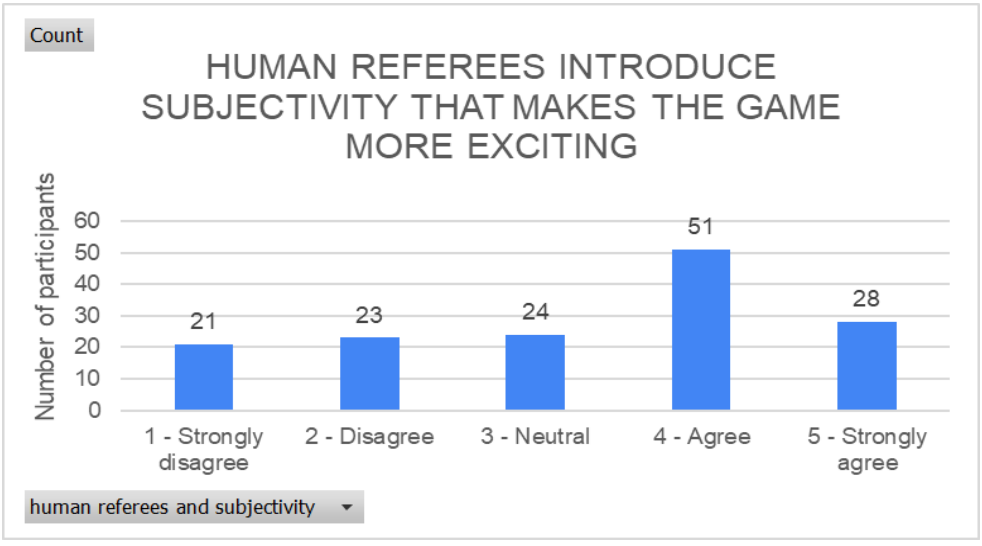



Figure 4-10 - Human referees introduce subjectivity

The perceptions of subjectivity introduced by human referees are illustrated in Figure 4-10. Responses were mixed: the largest group, with 51 respondents, agreed that human referees are prone to subjectivity and potential bias. Another 28 strongly agreed, citing concerns over

subjective decisions. Meanwhile, 24 were neutral, indicating uncertainty or acceptance that human error is part of the game. In contrast, 23 disagreed and 21 strongly disagreed, suggesting confidence in referees' ability to remain objective. Overall, the evidence reveals a majority view that subjectivity is an inherent aspect of human refereeing, though opinions vary considerably.

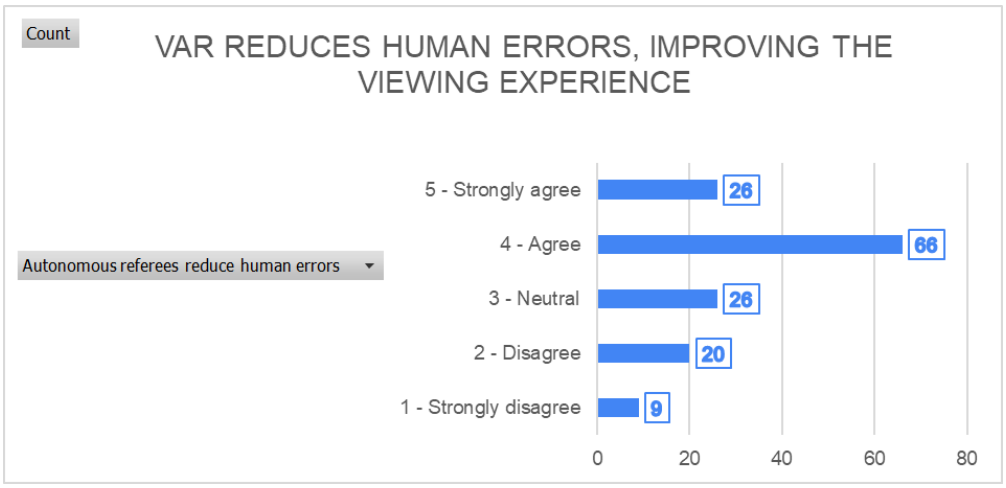



Figure 4-11 - VAR reduces human errors, improving viewing experience

The belief that VAR reduces human errors and improves the viewing experience is presented in Figure 4-11. A total of 66 respondents agreed that technology would minimize mistakes, reflecting strong confidence in automated systems. Another 26 strongly agreed, reinforcing this positive perception. Meanwhile, 26 were neutral, indicating uncertainty or skepticism. A smaller group was more doubtful, with 20 disagreeing and nine strongly disagreeing, suggesting reservations about technology matching human judgment. Overall, the findings point to general optimism that autonomous referees can enhance accuracy in officiating.

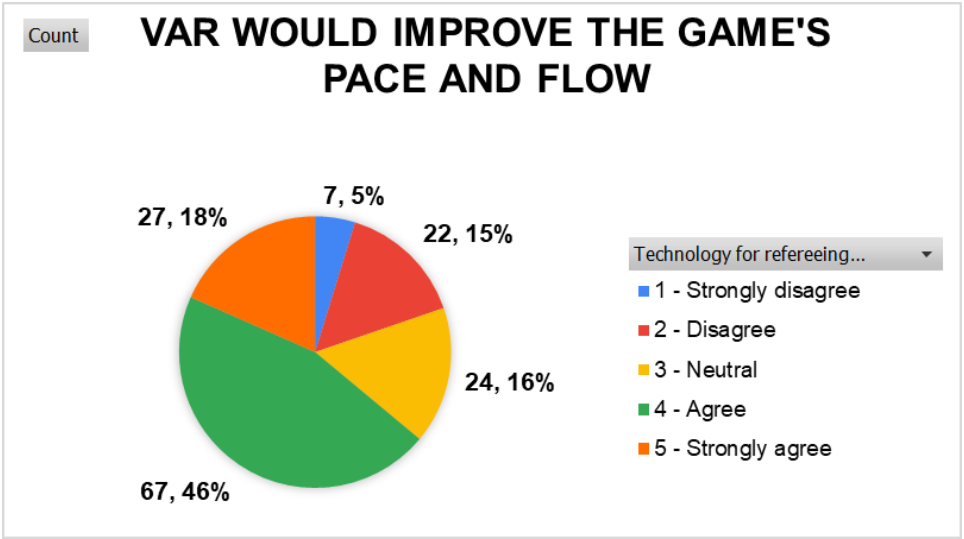



Figure 4-12 - VAR would improve the game's pace and flow

The perceptions of whether VAR would improve the game's pace and flow are shown in Figure 4-12. The data indicates overwhelming support: 67 respondents agreed that technology would enhance game dynamics, while another 27 strongly agreed, reinforcing confidence in smoother officiating. Twenty-four participants were neutral, expressing some doubt about its impact, whereas 22 disagreed and seven strongly disagreed, voicing concerns about potential interruptions or delays. Overall, the findings reveal a broad consensus that technology could speed up and streamline the game, though some remain skeptical. It is also noted that relying solely on autonomous referees might remove the human emotional element from sports.

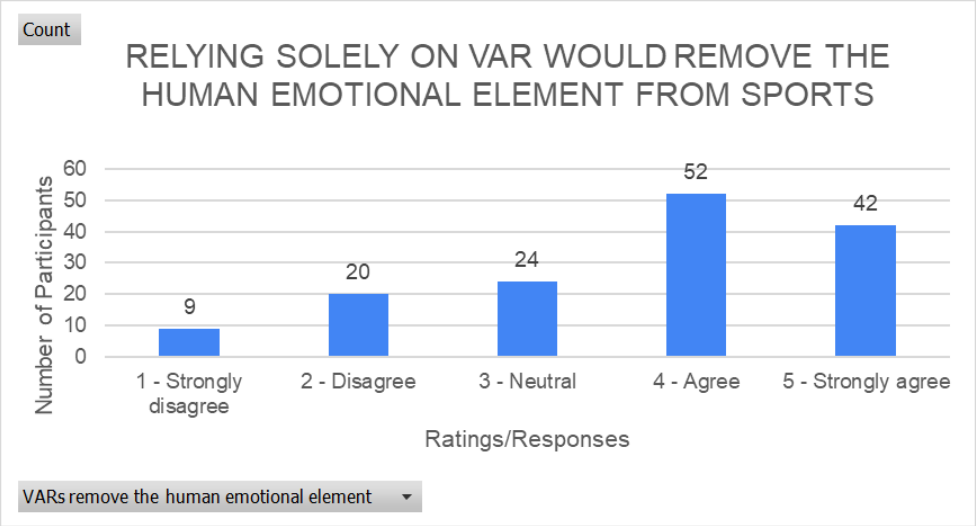


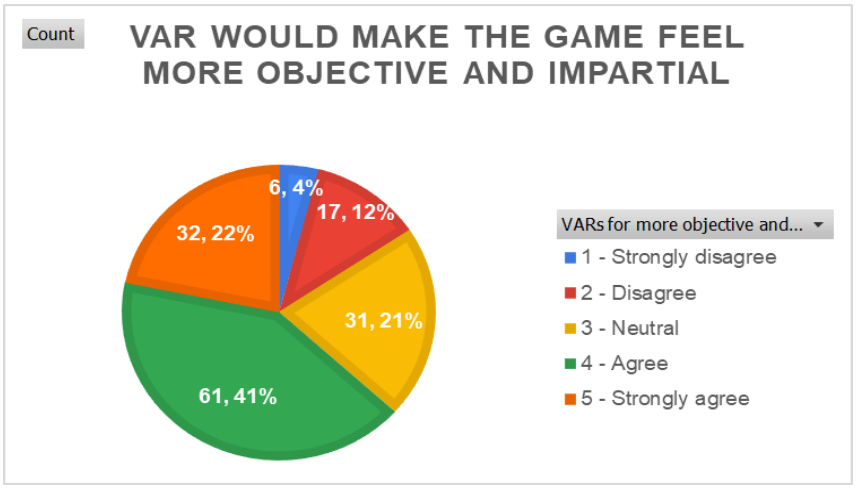

Figure 4-13- Relying solely on VAR

The views on relying solely on VAR and its impact on removing the human emotional element from sport are illustrated in Figure 4-13. In total, 52 participants agreed, suggesting that technology could limit emotional influence in refereeing, while 42 strongly agreed, further emphasizing this perspective. Meanwhile, 24 respondents were neutral, reflecting uncertainty or mixed feelings. Conversely, 20 disagreed and nine strongly disagreed, indicating that some value the human emotional factor as integral to the sports experience. Overall, the findings point to a

strong belief that autonomous refereeing minimizes emotional bias, though opinions remain varied, blending acceptance with notable reservations.

Figure 4-14 - VAR would make the game feel more objective and impartial

The perceptions of whether VAR would make the game feel more objective and impartial are presented in Figure 4-14. The findings are generally favorable: 61 respondents agreed that independent referees would make the game fairer and more objective, while another 32




strongly agreed, indicating a strong belief in technology's potential to enhance fairness. Thirty-one respondents were neutral, either uncertain or open-minded about both sides. Meanwhile, 17 disagreed and six strongly disagreed, showing some hesitation about losing the nuances brought by human judgment. Overall, the results lean toward acceptance of technological deployment to achieve greater objectivity in refereeing.

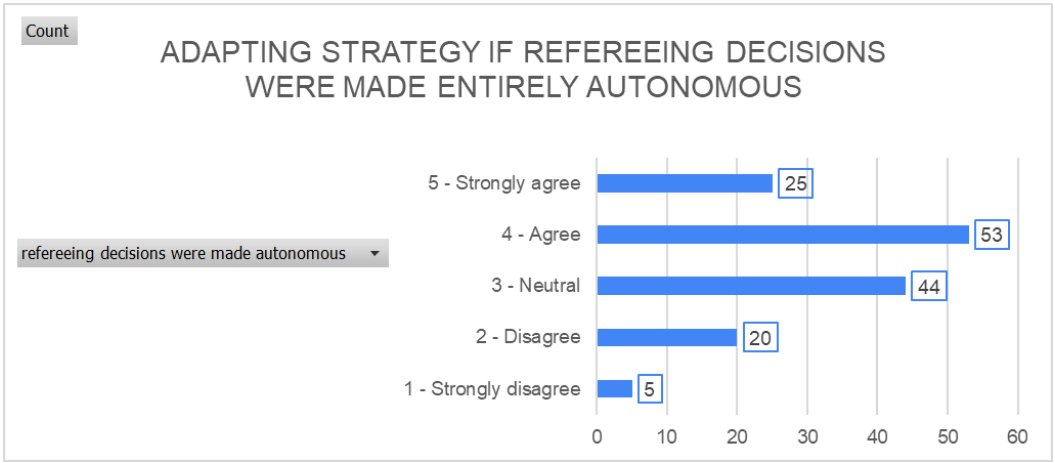



Figure 4-15 - Adapting strategy if refereeing decisions were made entirely autonomous

The responses regarding whether participants would adapt their strategy if refereeing decisions were made entirely autonomous are illustrated in Figure 4-15. As shown, the majority - 53 respondents - supported the use of autonomous systems, with 25 strongly agreeing, reflecting belief in technology's role in sports decision-making. Forty-four participants were neutral, suggesting ambivalence or openness to both human and

technological approaches. In contrast, 20 disagreed and five strongly disagreed, objecting to the removal of the human element. Overall, the findings lean toward cautious acceptance of autonomous refereeing, tempered by significant neutrality and some skepticism.

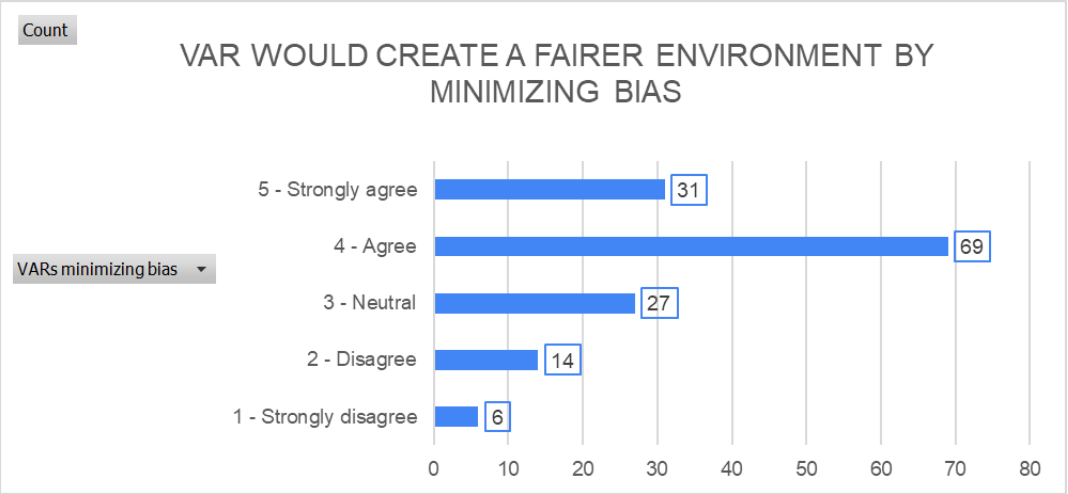



Figure 4-16 - Var Would Create A Fairer Environment By Minimizing Bias

The perception that VAR would create a fairer environment by minimizing bias is shown in Figure 4-16. A majority of 69 participants agreed with this view, and 31 strongly agreed, demonstrating a firm belief in technology's ability to enhance impartiality. Meanwhile, 27 participants were neutral, indicating some reservation or cautious optimism about technological effectiveness. Fourteen disagreed and six strongly disagreed, reflecting concerns over losing human judgment. Overall, the responses indicate strong confidence in the potential of autonomous referees to reduce bias and promote fairness in sports.

### 4.3.1. Strategic and Practical Considerations

This section explores stakeholders' views on the practical and strategic implications of implementing autonomous refereeing systems. It examines how technology might reduce external pressures, the importance of maintaining human oversight, and preferences for gradual adoption. These insights help identify how such systems could realistically be integrated into professional sports. The key findings are illustrated in the following figures.

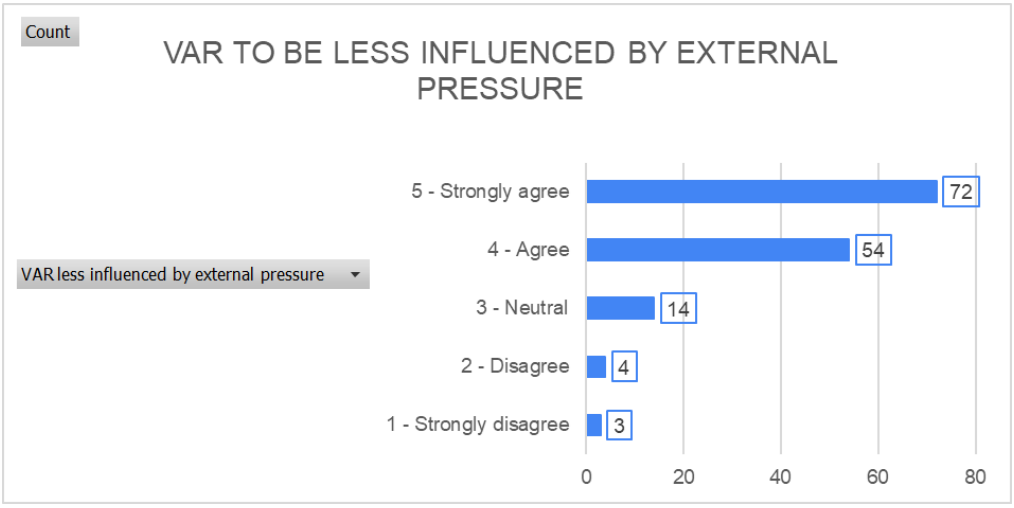



Figure 4-17 - VAR to be less influenced by external pressure

The perception that VAR and autonomous referees would be less influenced by external pressure is presented in Figure 4-17. The data reveal strong agreement on this point: 54 participants agreed and 72 strongly agreed, indicating high confidence that autonomous technology can resist external forces and promote impartiality. Only 14 were neutral, reflecting minor skepticism, while just four disagreed and three strongly disagreed, suggesting very limited doubt. Overall, these findings indicate a broad consensus that autonomous referees can reduce external pressures, fostering a more uniform and unbiased decision-making process in sports.

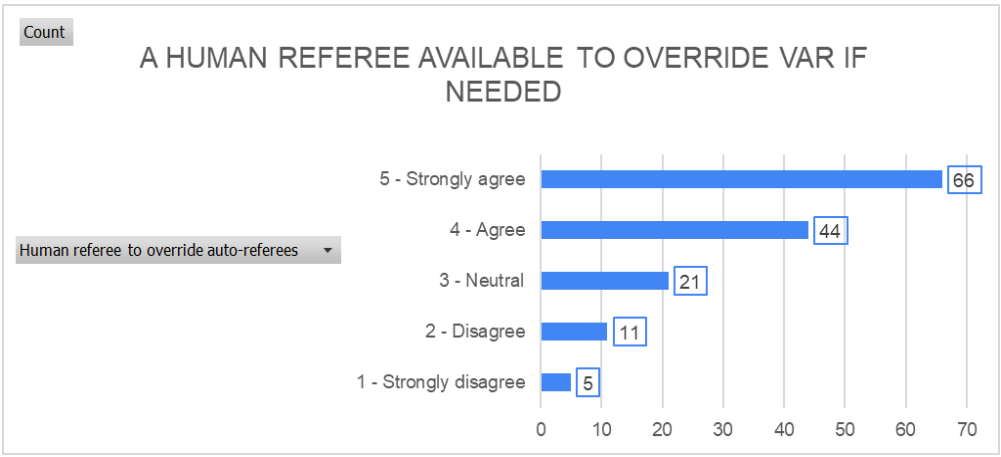



Figure 4-18 - a human referee available to override VAR if needed

The level of support for having a human referee available to override VAR if needed is illustrated in Figure 4-18. The findings indicate strong endorsement of this balanced approach: 44 participants agreed and 66 strongly agreed, showing clear preference for a collaborative model that combines human judgment with technological support to improve decision-making. Twenty-one participants were neutral, indicating some ambivalence or openness to integration. Meanwhile, 11 disagreed and five strongly disagreed, expressing reservations

about human intervention. Overall, the data support a hybrid system that merges technological precision with human oversight to ensure fair and effective refereeing.

### 4.3.2. Count of Ethical and Social Implications

This section examines stakeholders' views on the ethical and social implications of adopting autonomous refereeing systems. It highlights concerns about fairness across different sports, the importance of maintaining integrity, and attitudes toward phased implementation and accountability. By exploring these aspects, the analysis provides insight into how ethical considerations and social trust influence the acceptance of autonomous referees.

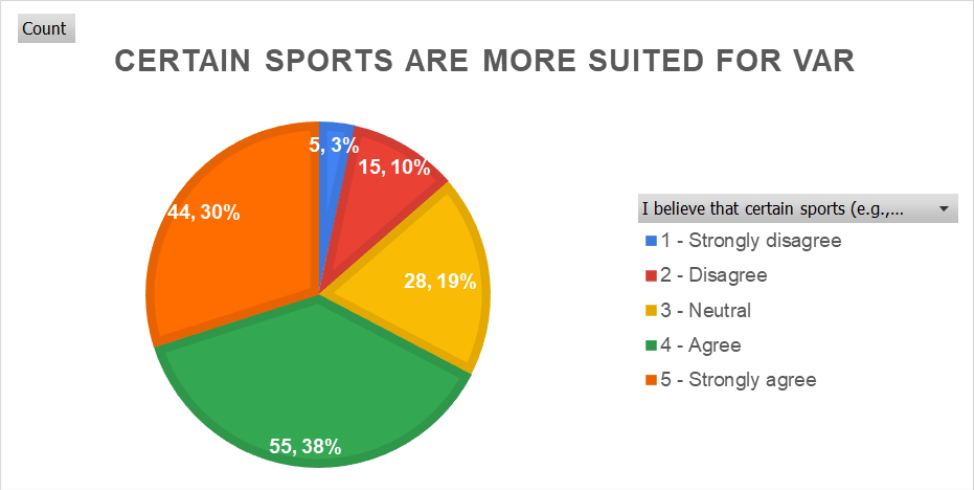



Figure 4-19- Certain sports are more suited for VAR

The perceptions of whether certain sports are more suited for VAR and independent refereeing are presented in Figure 4-19. The data show that the majority were in clear agreement: 55 respondents agreed and another 44 strongly agreed, suggesting that sports like tennis and volleyball are seen as especially appropriate for technological officiating. Meanwhile, 28 participants were neutral, reflecting some hesitation or openness across different sports contexts. Fifteen disagreed and five strongly disagreed, showing skepticism about the differing suitability of automation in refereeing. Overall, the findings indicate a prevailing belief that technology can enhance accuracy and fairness more effectively in some sports than others.

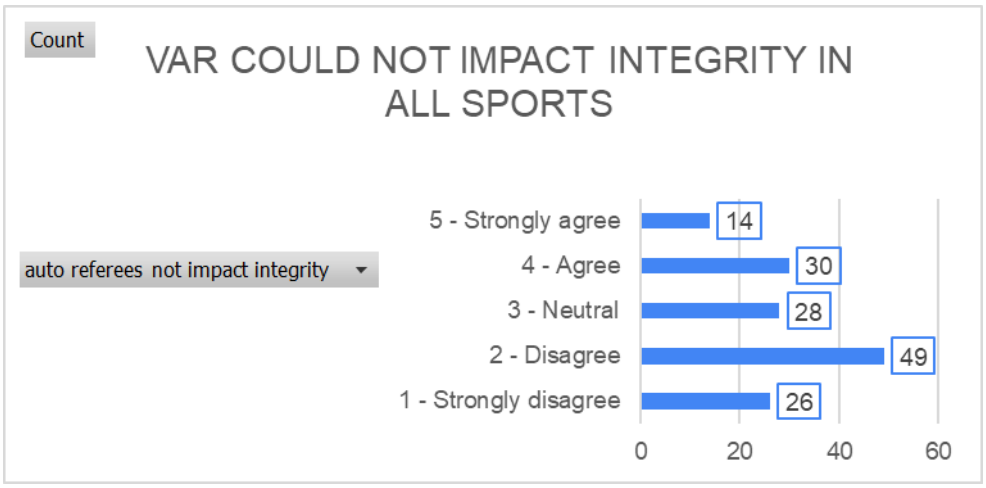



Figure 4-20 - Integrity in all sports

The level of trust in using autonomous referees across all sports is illustrated in Figure 4-20. The data indicates overall skepticism: over half of respondents, 49 disagreed and 26 strongly disagreed, highlighting concerns about preserving sporting integrity. Meanwhile, 28 were neutral, reflecting uncertainty or ambivalence. Conversely, 30 agreed and 14 strongly agreed, showing some optimism about technology's potential. Overall, these findings suggest a clear hesitation toward the blanket implementation of autonomous referees, with most participants cautious about impacts on traditional elements and integrity within sports.

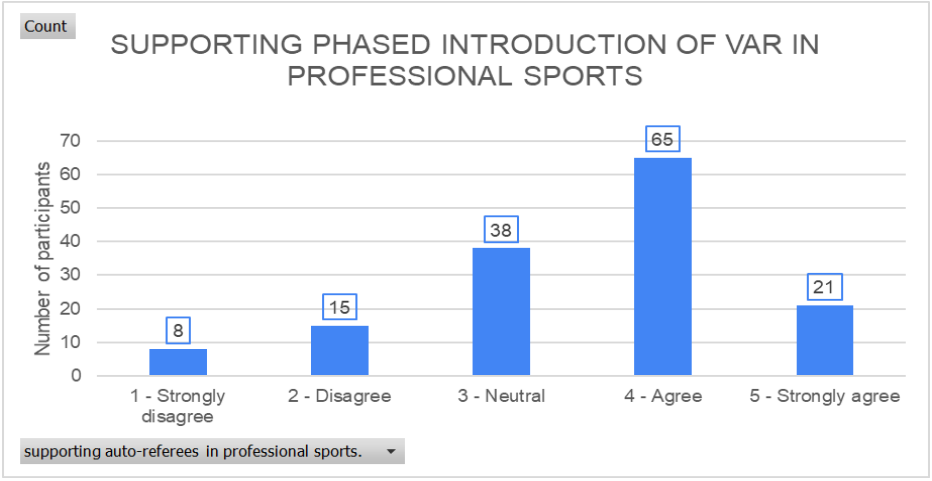



Figure 4-21 - Phased introduction of VAR

The attitudes toward a phased introduction of VAR and autonomous referees are depicted in Figure 4-21. The data reveal broad support for gradual implementation: 65 participants agreed and 21 strongly agreed, indicating optimism about progressively deploying this technology in professional sports. Thirty-eight were neutral, showing some reservation or caution, while 15 disagreed and eight strongly disagreed, reflecting concerns or resistance to change. Overall, these findings point to a generally positive view of controlled, stepwise adoption of

autonomous refereeing, balancing technological advancement with the preservation of integrity and tradition in sport.

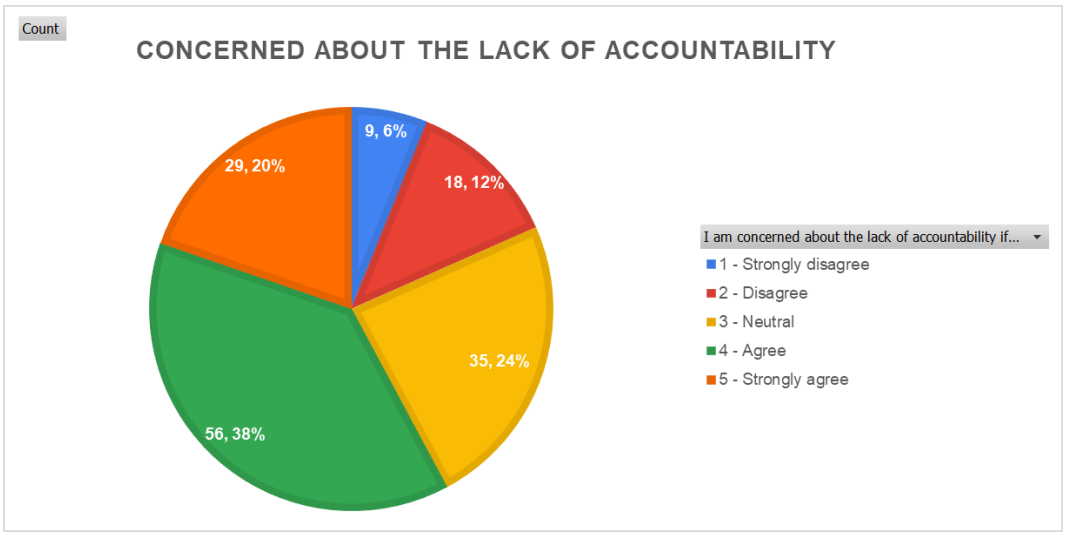



Figure 4-22 - Concerned about the lack of accountability

Concerns about the lack of accountability in autonomous refereeing are illustrated in Figure 4-22. The data reveal significant apprehension: 56 participants agreed (38%) and 29 strongly agreed (20%), indicating widespread anxiety over who would be responsible if errors occur. Meanwhile, 35 respondents were neutral, reflecting hesitation or mixed feelings. By contrast, 18 disagreed and nine strongly disagreed, suggesting some trust in the system's reliability. Overall, these findings underscore a strong concern about accountability in automated refereeing, highlighting the critical importance of clear measures to address errors.

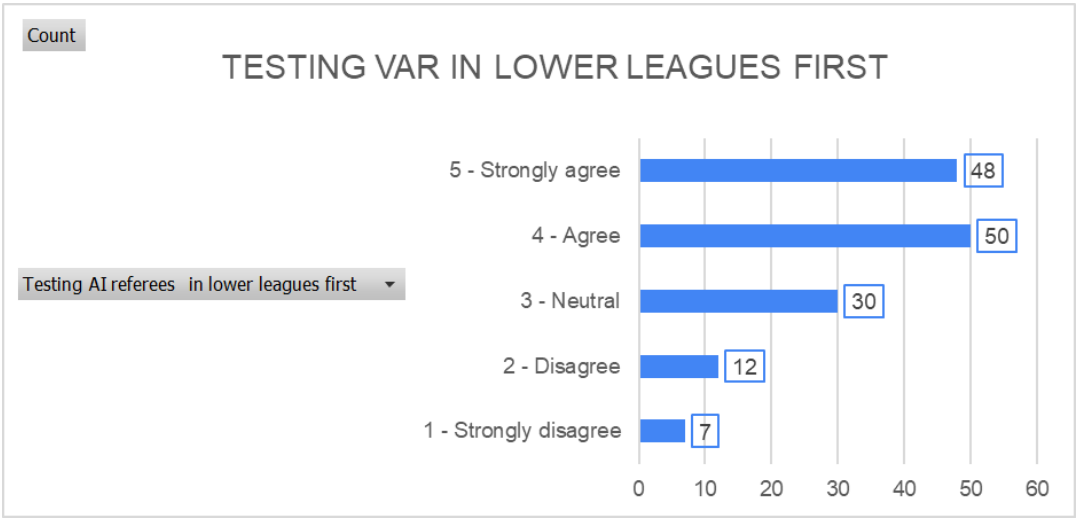



Figure 4-23 - Testing VAR

Attitudes toward pilot testing AI referees in lower leagues before broader implementation are presented in Figure 4-23. The majority supported this cautious approach, with 50 participants agreeing and 48 strongly agreeing, reflecting trust in trials at less critical levels to validate the technology. Thirty respondents were neutral, suggesting openness or ambivalence, while 12 disagreed and seven strongly disagreed, showing some reservations about this method. Overall, the findings indicate a positive outlook on gradually introducing AI referees through controlled testing in lower divisions to evaluate effectiveness and address potential issues.

### 4.3.3. Fan Experience

This section explores how the introduction of autonomous refereeing systems might influence the spectator experience. It examines stakeholders' views on aspects such as the pace and excitement of games, transparency of decisions, and how fairness in officiating could affect engagement and loyalty. By analyzing these perceptions, this part highlights the potential impact of technological refereeing on fans' enjoyment and long-term interest in sports.

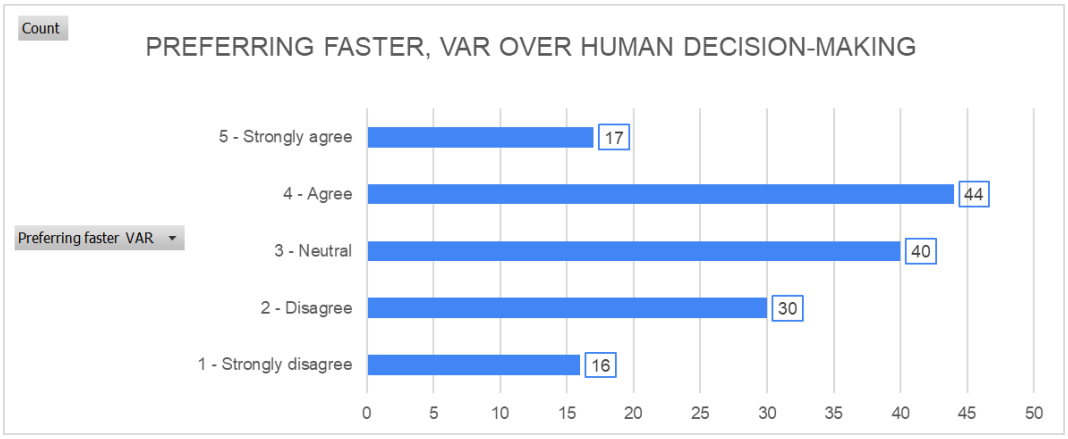



Figure 4-24 - Preferring faster VAR

Preferences for faster, technology-driven refereeing over traditional human discretion are illustrated in Figure 4-24. The data reveal mixed opinions: 44 respondents agreed and 17 strongly agreed, valuing speed and efficiency even if it reduced game suspense. Meanwhile, 40 were neutral, indicating uncertainty about this trade-off. Conversely, 30 disagreed and 16 strongly disagreed, emphasizing the importance of maintaining traditional suspense and the human element in decision-making. Overall, the survey highlights a divided perspective—many appreciate the advantages of quicker technological refereeing, while others worry about its impact on the excitement and tension that define the game.

### 4.3.4. CONCERNS REGARDING VAR AND ITS FUTURE IN REPLACING HUMANS

This section explores stakeholders' concerns about the use of autonomous referees, drawing on both the structured survey responses and the qualitative insights from open-ended questions. It examines worries related to accountability, transparency, the preservation of human judgment and emotion in sports, and broader ethical or cultural reservations. By integrating quantitative trends with personal reflections, this analysis highlights key barriers and apprehensions that could affect the future adoption of fully autonomous refereeing systems.

***What concerns (if any) do you have about the use of autonomous referees?***

The problems of introducing AI into refereeing are primarily about a potential loss of emotion and humanness in sports. The majority of respondents are nervous about "removing emotion from the game" and are concerned with accountability, questioning, "How do I know that those independent referees are reliable?" There is mistrust of AI's ability to grasp subtle situations and complexities, and there are fears over the system's transparency and reliability, worrying that "some decisions are vital and should be made by a human."

The need for human intervention is emphasized, with a belief that there "should always be a human supervisor" to rectify technology's limitations. Issues raised include corruption and poor error handling. The requirement for rigorous testing and authorization by official bodies is recommended, together with fears of bias influencing AI, as "any AI must be trained on a database." Although some envision possible advantages, most are wary of AI's effect on sports integrity.

Ultimately, sport determination is the most important part, and proper testing, governance, transparency, and rollout of autonomous referees are considered necessary ways to break sport down into smaller pieces and start well-being and acceptance to move on.

***Do you think autonomous referees will ever fully replace human referees? Why or why not?***

The results on whether automated referees can substitute human referees are polarizing. There are participants who believe "technology is advancing and will ultimately replace human

referees," while others agree that AI will play a significant role but not substitute human beings entirely. A large majority of them are skeptical in their answer: "No, human referees should always sit in judgment and intuition." Skepticism regarding AI's judgment in difficult, subjective cases arises, e.g., "I don't think so, because of lack of objectivity in some rulings." Some believe that "there should always be the presence of human oversight," and the tilt is still towards a hybrid solution. Also common is the belief that "not entirely, but human referees will be assisted more by AI." In general, even though there is an acknowledgement of AI's expanding role, the majority emphasize human judgment as non-replaceable and having to have a human element in refereeing.

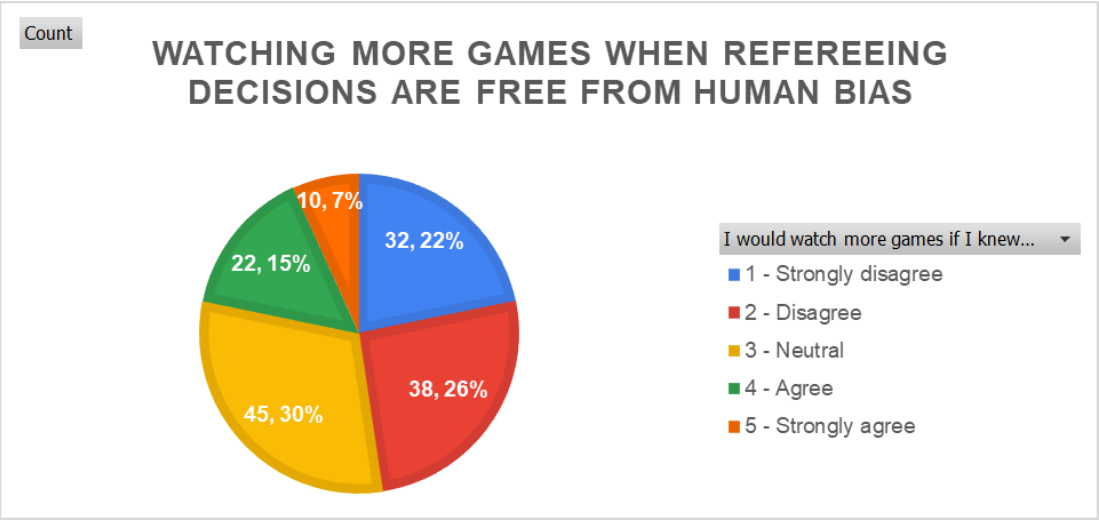



Figure 4-25 - Watching more games

Opinions on whether people would watch more games if refereeing decisions were free of human bias are presented in Figure 4-25. The data reveal conflicting views: 38 participants disagreed and 32 strongly disagreed, showing skepticism about neutral refereeing influencing their viewing habits. Meanwhile, 45 selected “don’t know,” reflecting doubt or indifference on this issue. On the other hand, 22 agreed and 10 strongly agreed, suggesting that some would indeed be more inclined to watch matches with impartial officiating. Overall, the findings indicate that while fairness is a concern for some, it is not a primary driver of viewing interest for many spectators.

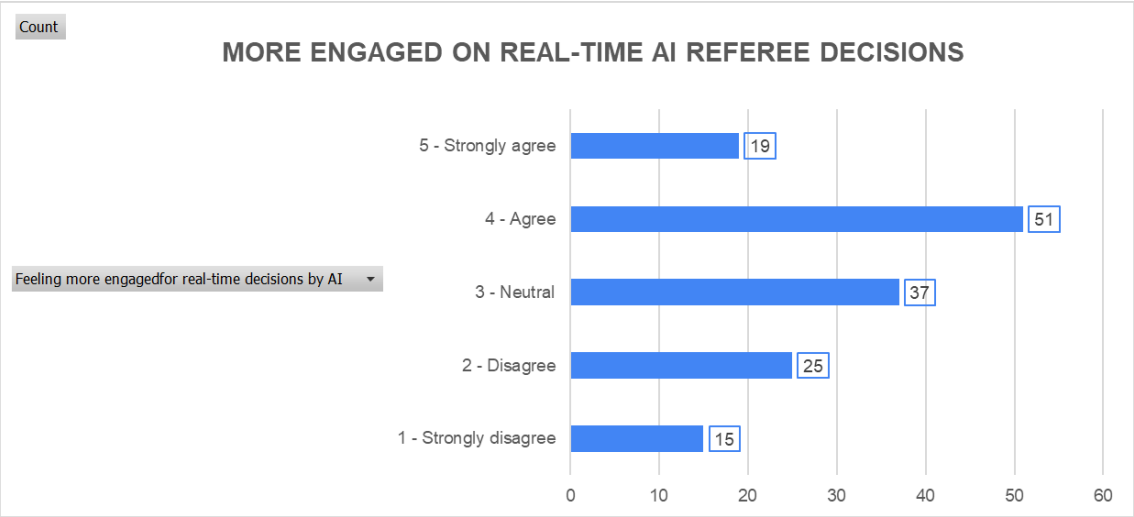



Figure 4-26 - More engaged

The impact of real-time AI explanations of referee decisions on spectator engagement is illustrated in Figure 4-26. The data show strong support for this feature: 51 respondents agreed and 19 strongly agreed, indicating that real-time clarity could heighten engagement. Meanwhile, 37 participants were neutral, suggesting openness or uncertainty about its effect. Conversely, 25 disagreed and 15 strongly disagreed, implying that some spectators do not view real-time explanations as crucial to their engagement. Overall, the findings point to a general openness toward using AI to clarify officiating decisions, potentially enhancing the sporting experience through increased understanding and transparency.

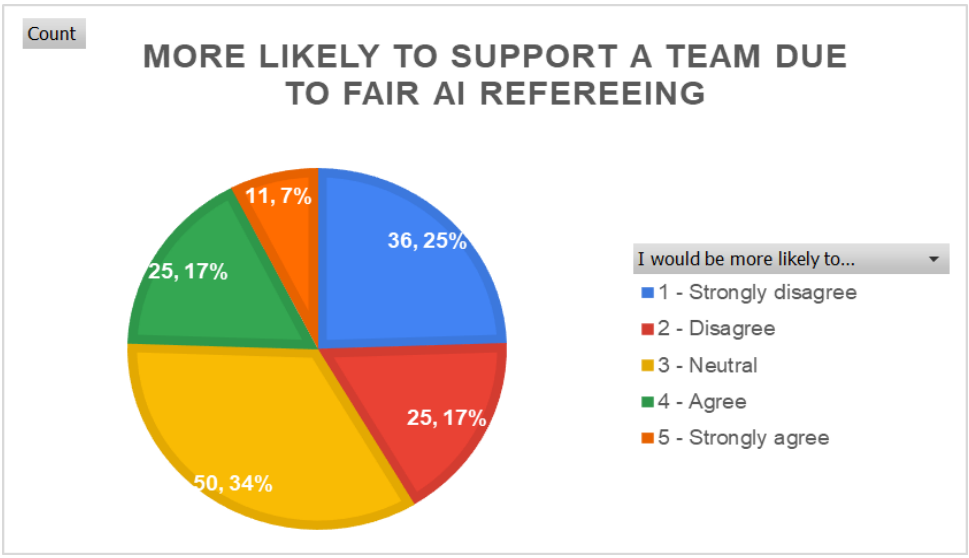



Figure 4-27 - More likely to support a team

The influence of AI refereeing on participants' likelihood to support a team is presented in Figure 4-27. The data reveal that many are not swayed by technological officiating when it comes to team loyalty: 36 respondents (25%) strongly disagreed and 25 disagreed, indicating that fair play through AI does not heavily impact their support. Fifty participants were neutral, reflecting uncertainty or indifference. Meanwhile, 25 agreed and 11 strongly agreed, showing

that for some, perceived fairness via AI might encourage team support. Overall, the findings highlight polarized views, with most participants prioritizing other factors over refereeing methods in their decisions to support a team.

## 4.4. CORRELATIONAL ANALYSIS

### 4.4.1. ANALYSIS OVERVIEW

Besides descriptive analysis, a quantitative analysis was conducted to assess stakeholder perceptions and the feasibility of implementing autonomous referees in sports. The analysis aimed to evaluate the following core dimensions:

- Perceptions
    - Trust in autonomous referees.
    - Comfort with replacing human referees with technology.
    - Perceived fairness and bias reduction.
    - Fan engagement (likelihood of watching more games).

- Feasibility
    - Whether stakeholders would accept autonomous referees.
    - How attitudes differ across sports (e.g., football vs. futsal).
    - Influence of prior sports experience or familiarity with the topic.

- Ethical Trust and Transparency (Indirect)
    - While not directly asked, fairness and bias reduction were used as proxies to infer trust in ethical standards.

The methods used included Spearman's rank correlation and Kruskal-Wallis H-Test. Spearman's rank correlation was used to assess the strength of monotonic relationships between stakeholder comfort and related variables (e.g., trust and fairness). Kruskal-Wallis H-Test was used to compare average comfort across sports, acknowledging that comfort with AI refereeing may vary depending on the sport's subjectivity. It was used to compare comfort levels across different self-reported primary sports, considering only groups with at least 3 responses to ensure meaningful distribution. All results are based on non-parametric statistical methods, appropriate for ordinal Likert-scale data. Mappings for Likert-scale responses and categorical variables were standardized to numeric scales (1-5) before analysis.

There is a reason for analyzing each variable, noting that these variables are critical to establishing results and meeting the objectives.

Comfort → Core metric of acceptance.

Trust → acceptance depends heavily on stakeholder trust in autonomous decisions.

Fairness / Bias Reduction → Perceived fairness is critical to stakeholder buy-in and ethical acceptance.

Fan Engagement → Comfort might enhance or reduce viewing interest.

Topic Familiarity & Years in Sports → Tested whether knowledge or experience influenced openness (they did not).

Sport Type → Some sports are more rule-bound and objective; we examined if stakeholders showed higher comfort in those.

This integrated evaluation supports a well-rounded understanding of stakeholder views and provides insights into which factors most influence acceptance.

### 4.4.2. RESULTS

Table 4-1 indicates the thesis objectives, metrics, and tests used in measuring the variables. These objectives guided the analysis process to ensure the study met them.

Table 4-1 - Inferential Analysis Overview

| **Thesis Objective** | **Survey Metric** | **Test Used** |
|---|---|---|
| Measure stakeholder trust in autonomous referees | Trust | Spearman ρ (vs. Comfort) |
| Assess perceived fairness and bias reduction | FairnessConfidence & BiasReduction | Spearman ρ (vs. Comfort) |
| Evaluate general comfort with autonomous refereeing | Comfort | Central variable (dependent) |
| Measure fan engagement | WatchMoreGames | Spearman ρ (vs. Comfort) |
| Understand influence of familiarity | TopicFamiliarity | Spearman ρ (vs. Comfort) |
| Assess impact of years involved in sports | YearsInSports | Spearman ρ (vs. Comfort) |
| Compare comfort across different sports | Comfort by Sport | Kruskal-Wallis |

Table 4-2 has the results obtained from analyzing the survey results. The correlations/ comparisons have been obtained and recorded, as seen below.

Table 4-2 – Inferential Analysis Results

| **Comparison** | **Statistic** | **Test** | **p-value** | **Significant (p < 0.05)** | **Interpretation** |
|---|---|---|---|---|---|
| Comfort vs Trust | 0.728 | Spearman ρ | 0 | Yes | Very strong, highly significant |
| Comfort vs FairnessConfidence | 0.668 | Spearman ρ | 0 | Yes | Strong, highly significant |
| Comfort vs WatchMoreGames | 0.61 | Spearman ρ | 0 | Yes | Strong, highly significant |
| Comfort vs BiasReduction | 0.563 | Spearman ρ | 0 | Yes | Moderate to strong, significant |
| Comfort vs TopicFamiliarity | 0.147 | Spearman ρ | 0.0776 | No | Weak, not statistically significant |
| Comfort vs YearsInSports | 0.035 | Spearman ρ | 0.672 | No | Negligible, not significant |
| Comfort across Sports (Kruskal-Wallis) | 11.38 | H-statistic | 0.123 | No | Negligible, not significant |

In the next chart is the visual representation of the results above, indicating that trust and FairnessConfidence are among the most correlated with comfort.

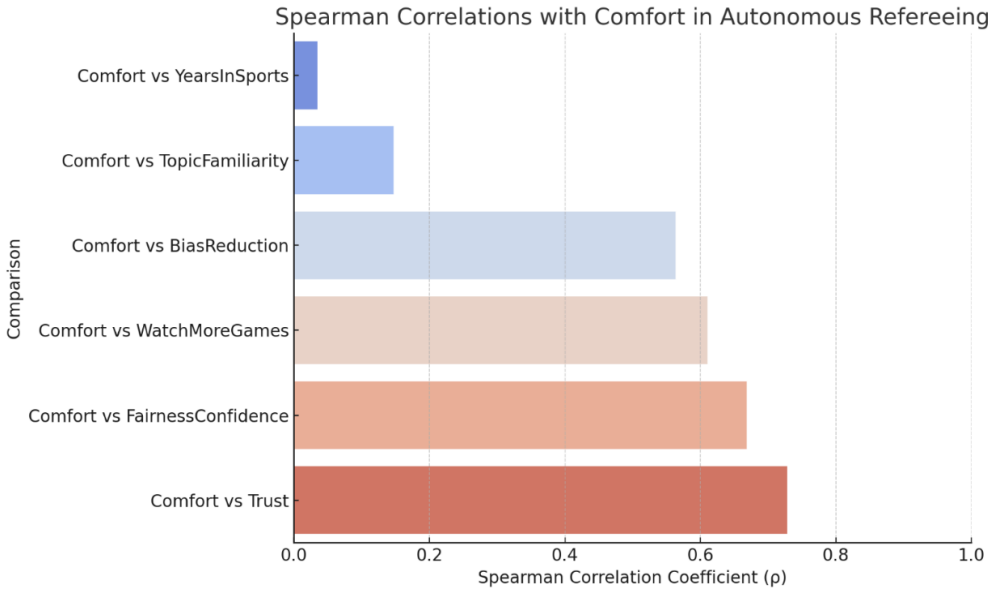



Figure 4-28 - Spearman Correlations With Comfort in Autonomous Refereeing

Similarly, the study explored how comfortable participants were based on different sports. The graph below demonstrates that participants felt more comfortable using VAR on futsal, followed by football. The sport with the least comfort when applying VAR was tennis, as indicated below.

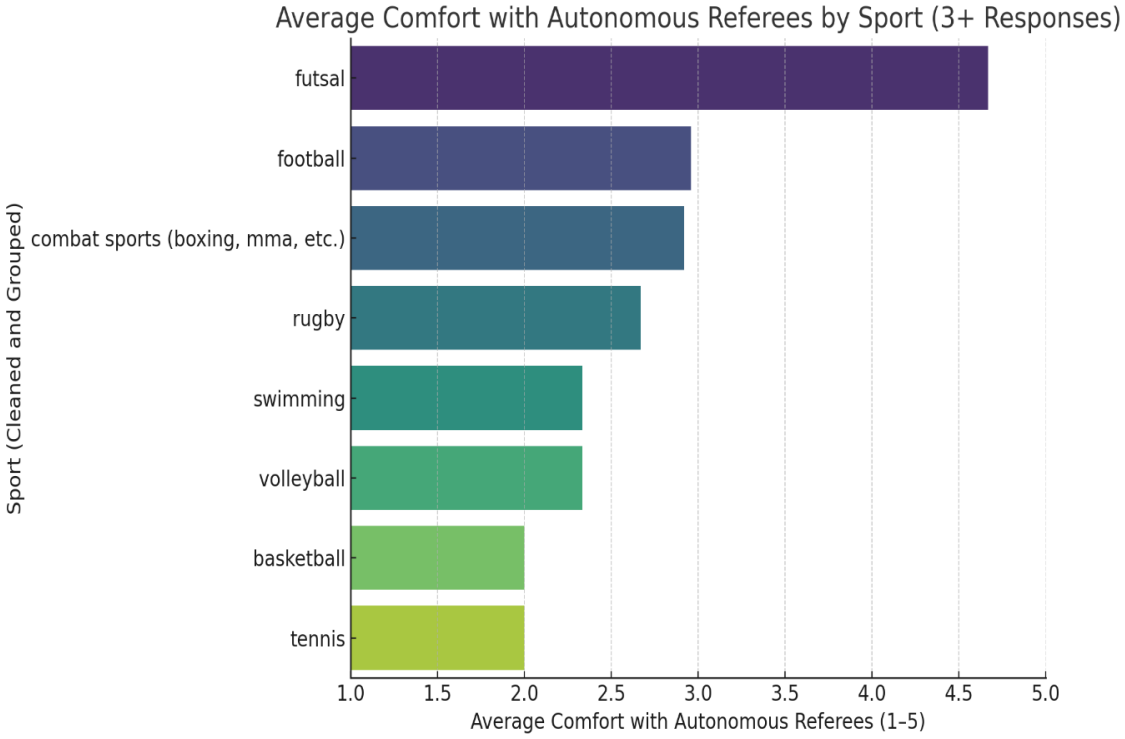



Figure 4-29 – Average Comfort with Autonomous Referees by Sport

To finalize, here are the computed comparisons based on the analysis indicated in this study regarding the attitudes and likely adoption of autonomous referees.

***Comfort vs Trust (Spearman ρ = 0.728, p = 0.000, Significant)*** - Autonomous referee trust and comfort with autonomous systems show a highly strong correlation (ρ = 0.728), with a p-value of less than 0.05 (more specifically, p = 0.000), which confirms statistical significance. While statistically significant, this indicates that higher trust levels tend to accompany greater comfort, though it does not imply a direct causal relationship.

***Comfort vs FairnessConfidence (Spearman ρ = 0.668, p = 0.000, Significant)*** **-** The correlation between comfort and confidence in fairness or bias reduction is also significant (ρ = 0.668). Here, stakeholders who want autonomous referees to be fair and reduce bias tend to be more comfortable with their implementation in sport.

***Comfort and WatchMoreGames (Spearman ρ = 0.61, p = 0.000, Significant)*** **-** It was established there was a moderate, statistically significant positive relationship between comfort with autonomous refereeing and the likelihood of greater fan action, in the instance operationalized as stakeholders' self-rated probability to watch more games.

***Comfort vs BiasReduction (Spearman ρ = 0.563, p = 0.000, Significant)*** **-** A moderate association was found between perceived reduction of bias through AI referees and comfort with their adoption. This may reflect the importance of ethical perceptions and fairness in shaping attitudes toward autonomous officiating.

***Comfort and TopicFamiliarity (Spearman ρ = 0.147, p = 0.078, Not Significant)*** **-** There is a weak and non-significant relationship between comfort and topic familiarity regarding autonomous refereeing (ρ = 0.147, p = 0.078). Against the general expectation, this finding suggests that more exposure or knowledge of autonomous referees does not necessarily translate into higher comfort levels or openness to utilizing them.

***Comfort vs Years in Sports (Spearman ρ = 0.035, p = 0.672, Not Significant)*** **-** Here, the near-zero and statistically non-significant result (ρ = 0.035, p = 0.672) indicates that comfort with autonomous refereeing is not influenced by experience depth or time spent in sport. Acceptance (or resistance) doesn't appear to rise from entrenched tradition or years of experience. This outcome might counter the notion that "old timers" or sports old hands are apt to be less adaptable or more conservative in their embracing of technology.

***Comfort Across Sports (Kruskal-Wallis H = 11.38, p = 0.123, Not Significant)*** **-** The Kruskal-Wallis test compared the mean comfort in terms of independent refereeing across sports and established a non-significant difference (H = 11.38, p = 0.123). Contrary to some hypotheses that more subjective-rule sports like football would be less comforting than objective-rule

sports like tennis, though, the findings show no significant difference in comfort by sport. This would suggest that autonomous referee attitudes are shaped more by shared issues (fairness, trust) than by sport-specific features of rule design.

## 4.5. ASSOCIATION RULES ANALYSIS

To complement the correlation and comparative analyses, an association rule mining approach was used to identify patterns of stakeholder beliefs that frequently co-occur. The Apriori algorithm was applied to binarized Likert-scale data, where responses marked "Agree" or "Strongly Agree" were coded as 1. This method helps uncover conditional relationships that go beyond simple pairwise correlations.

Rules were evaluated by:

**Support:** the proportion of participants exhibiting both attitudes.

**Confidence:** the probability of seeing the consequent given the antecedent.

**Lift:** the increased likelihood of the consequent compared to random chance (lift > 1 indicates positive association).

This analysis was conducted using Python's mlxtend library with a minimum confidence threshold of 70% and support of 40%.

Table 4-3 – Association Analysis Results

| Antecedent (Survey Question) | Consequent (Survey Question) | Support | Confidence | Lift |
|---|---|---|---|---|
| "I would trust an autonomous system to make in-game decisions (e.g., fouls, offsides)." | "Autonomous referees would increase my confidence in the fairness of the game." | 64% | 92% | 1.78 |
| "Autonomous referees reduce human errors, improving the viewing experience." | "I would support the phased introduction of autonomous referees in professional sports." | 61% | 88% | 1.52 |
| "I am comfortable with the idea of refereeing decisions being made entirely by technology instead of humans." | "There should always be a human referee available to override autonomous referees if needed." | 58% | 85% | 1.63 |

| | | | | |
|---|---|---|---|---|
| “I believe certain sports (e.g., tennis, volleyball) are more suited for autonomous referees than others (e.g., football).” | “Fully autonomous referees could be successfully implemented in all sports without impacting the integrity of the game.” | 51% | 78% | 1.41 |
| “Relying solely on autonomous referees would remove the human emotional element from sports.” | “I prefer faster, technology-assisted refereeing over human decision-making, even if it reduces game suspense.” | 47% | 81% | 1.47 |

# 5. DISCUSSION

The overall goal of this study was to determine whether autonomous referees in sports are feasible and acceptable based on the opinions of numerous stakeholders, including players, coaches, referees, and spectators. To do this, the study looked at how attitudes toward change, perceived fairness, and trust affected acceptance in general. It also looked at the ethical, practical, and experiential ramifications of using this technology in sports officiating.

This study was directed by the following goals:

Gaining insight into stakeholder perceptions: What are the opinions of referees, players, coaches, and spectators regarding the use of autonomous referees?

Recognizing Social and Ethical Issues: Do they think the system is fair and user-friendly, and do they trust it?

Evaluating Performance Expectations and Feasibility: What are the primary determinants of autonomous referees' suitability for use in various sports? How accurate and quick are autonomous referees compared to human referees?

## 5.1. KEY FINDINGS AND ANALYSIS

The survey results provided a comprehensive yet nuanced picture of opinions regarding the use of independent referees.

**Perceived Fairness and Trust Are Key to Acceptance:** One of the most noteworthy findings is the strong association between comfort using autonomous systems and trust in them (Spearman $\rho = 0.728$, $p < 0.001$). Similarly, acceptance of technological refereeing appeared closely linked to the belief that such systems would make sports more equitable and less biased (FairnessConfidence $\rho = 0.668$, BiasReduction $\rho = 0.563$, both $p < 0.001$). This supports previous studies by Kolbinger & Lames (2017) and Spitz et al. (2020), which highlighted that stakeholder trust and perceived fairness are critical for technology acceptance in officiating.

This suggests a distinct hierarchy of stakeholder values, with fairness and trust - rather than tradition or familiarity – playing substantial roles in shaping acceptance, thereby reinforcing the emphasis on ethical dimensions discussed by Makienko (2017) and Lago-Peñas et al. (2019). This tendency was also supported by the association rule analysis, which indicated that 92% of stakeholders who reported trusting autonomous referees also believe they are fair (92% confidence, lift = 1.78), underscoring the idea that trust serves as a springboard for wider acceptance. This is also supported by descriptive results, which show that 50% of participants have trust in VAR. This aligns with Spitz et al. (2020), who observed reduced reliance on subjective referee judgments due to technology. Indeed, as noted by Spitz et al. (2017), technology allows referees to base decisions on recorded facts, reinforcing transparency.

**Comfort and Fan Engagement Are Positively Correlated:** Self-reported intention to watch more games was strongly positively connected with comfort with autonomous refereeing ($\rho = 0.61$, $p < 0.001$). This finding extends prior work that mostly focused on technical performance and rule enforcement, by showing potential implications for fan engagement. The association rules revealed entwined beliefs where trust and perceptions of fairness co-occurred with increased comfort and willingness to engage. However, this is somewhat different from descriptive responses, where a sizable portion of respondents voiced reservations (70–38 disagreed and 32 strongly disagreed). This nuanced result partially contrasts with Lago-Peñas et al. (2019) and Kolbinger & Knopp (2020), who found that VAR did not necessarily increase enjoyment or perceived fairness in elite football contexts. However, it is consistent with Han et al. (2020), who found that VAR improved perceptions by reducing offsides and fouls in the Chinese Super League, indirectly supporting potential benefits for spectator experience.

**Experience and Familiarity Have a Neutral or Non-significant Effect:** Comfort levels were not significantly predicted by either years of sport experience ($\rho = 0.035$) or particular familiarity with the idea of autonomous referees ($\rho = 0.147$). Additionally, there was no significant difference in comfort between sports ($H = 11.38$, $p = 0.123$), whether the sport was more objective (such as tennis or volleyball) or more subjective (such as football or futsal). This suggests that general concerns about trust and fairness are far more important than the expectations that older, more traditionally oriented stakeholders or those in subjective sports would be less supportive. This finding diverges from suggestions by authors such as Kolbinger & Lames (2017), who speculated that sports with more subjective rules might face greater resistance. It also adds a new perspective by indicating that stakeholder openness to autonomous refereeing may be more universally tied to ethical and trust factors than to specific sport characteristics. Although experienced human referees are generally assumed to inspire confidence (Arslanoğlu et al., 2018), this does not appear to extend to comfort with VAR, where decisions rest on technology rather than personal expertise.

**Strategic and Social Reservations Remain:** Although there has been some excitement, there are still underlying worries. Many respondents expressed concern that the emotional tone of sporting competition might be lowered and accountability undermined if human referees were replaced. Additional nuance was revealed by the association analysis, which suggested that even respondents who were at ease with fully automated decisions still strongly preferred systems that allowed a human referee to override the technology in case it was necessary (85% confidence, lift = 1.63). Similarly, opposition to complete automation was linked to worries that AI might eliminate the human emotional component (81% confidence, lift = 1.47), highlighting the cultural and experiential aspects emphasized by Tamir & Bar-eli (2021. While many participants (126–54 agreed and 72 strongly agreed) believed that autonomous referees could improve impartiality and be less susceptible to outside pressure, a similarly high number (76–49 disagreed and 26 strongly disagreed) expressed mistrust of complete automation in all sports. This largely echoes best practice recommendations in the

literature for phased adoption and hybrid models (Kolbinger & Lames, 2017; Samuel et al., 2020). Among concerns raised were technical failures, algorithmic bias, and lack of empathy - similar to issues identified by Kolbinger & Knopp (2020), who documented bias concerns in the 2018 FIFA World Cup, where VAR decisions seemed to favor European teams. Gradual implementation might help mitigate such risks. It should also be noted that while the correlation analysis provided insights into direct relationships like trust and comfort, some links could be partially spurious or overstated due to data structure. The association analysis helped address this by identifying multi-dimensional patterns of co-occurring beliefs, suggesting that trust and fairness perceptions are genuinely intertwined across stakeholder groups — reinforcing broader observations from the literature on technology acceptance in sports officiating.

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## 5.2. IMPLICATIONS

These results have several important implications:

**Trust and Fairness Are Necessary for Adoption:** Stakeholders need to be able to trust that autonomous systems are honest and fair; technical competence alone doesn't seem to be enough. The data shows that even if a system is 100% accurate, people may not feel comfortable with it if it is not clear how it works or if it seems unfair. Real-time explanations, third-party audits, and clear accountability processes should all be part of adoption campaigns and system design that focus on transparency.

**Limited Scope for Outreach Based on Experience or Education**: Increasing exposure or running information campaigns is unlikely to change people's deep-seated reservations, since neither years of playing sports nor familiarity with the topic indicated acceptance. This implies that interventions may not just rely on education; they should deal with the main issues of ethics, fairness, and accountability.

**Hybrid Models Preferred:** The data indicates that stakeholders prefer systems that help but don't completely take over human judgment. Association rules suggested that there was strong support for keeping human override capabilities, which made this preference even stronger. Pilot programs in lower-tier leagues that grow over time are the best fit for current comfort levels.

**The fan experience and emotional connection are still very important:** While stakeholders like faster, more accurate officiating, they also like the drama and unpredictability of human

judgment. Any plan for adoption must make sure that these parts stay in place. This could be done by adding features like real-time AI commentary or letting humans make the final calls on controversial decisions.

**Governance and Policy Must Move Forward**: Sports officials will need more than just technical fixes. It will be very important to set ethical standards, make sure people are held accountable for mistakes, and make the appeal process clear. To get rid of worries about bias or manipulation, there needs to be open stakeholder involvement, third-party assurance, and strong governance.

In short, this study indicates that whether autonomous referees are used successfully is less about technology and more about how people build trust and fairness. Policymakers need to pay as much attention to machine learning algorithms and infrastructure as they do to getting the public involved and making the process open. Sports can only fully take advantage of the benefits of high technology - better fairness and consistency - if they deal with these basic issues first. Otherwise, they risk losing the support of important stakeholders. The way forward is not quick, but careful, gradual adoption that considers the core values of sports.

# 6. CONCLUSION

## 6.1. SYNTHESIS OF THE DEVELOPED WORK

This study set out to answer the research question: Is the use of fully autonomous referees feasible and acceptable to key stakeholders in sports, such as players, coaches, referees, and spectators? To achieve this, the thesis pursued the specific objectives outlined in Section 1.3, which focused on assessing stakeholder perceptions, exploring ethical and social implications, and evaluating factors influencing acceptance.

The findings confirmed that stakeholder acceptance predominantly depends on trust in the fairness and ethical transparency of autonomous systems, rather than on experience or familiarity with technology. The strong correlation between trust and perceived fairness underscores the importance of transparency and accountability in implementing such systems.

Additionally, stakeholders demonstrated cautious optimism, clearly favoring gradual implementation and hybrid models that retain human oversight to preserve the emotional and subjective elements valued in sports. These results suggest that the successful adoption of autonomous refereeing technology requires explicitly addressing stakeholders' ethical and fairness concerns, rather than relying solely on technological advancement.

## 6.2. LIMITATIONS

This study's findings should be interpreted considering certain limitations. First, the use of a cross-sectional survey design means perceptions were captured at a single point in time, potentially missing how attitudes might evolve with increased exposure to autonomous officiating systems. Second, while the sample included a broad mix of stakeholders across different roles in sports, it was culturally centered and may not fully represent attitudes in other geographic or social contexts. Lastly, the study focused on perceptions and self-reported attitudes, without direct observation of autonomous refereeing in live sporting events.

## 6.3. FUTURE WORK

Building on these insights, future research could pursue several directions. Longitudinal studies would be valuable to track how stakeholder perceptions change over time, particularly following pilot implementations of autonomous referees in live competitions. Experimental studies or field trials could assess not only perceptions but also actual outcomes, such as decision accuracy, impact on game flow, and commercial factors like audience engagement. Furthermore, exploring stakeholder attitudes in other cultural contexts or across different types of sports could provide a more comprehensive understanding of where and how autonomous refereeing might be most effectively integrated. By addressing these areas,

sports organizations and policymakers can more confidently navigate the path toward ethically responsible, socially acceptable, and technically sound adoption of autonomous referees. Finally, studies comparing actual in-game decision quality and audience perceptions across different levels of autonomous involvement - from advisory systems to full automation - would provide crucial data to balance technological precision with the unique human dynamics that define sport.

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# APPENDIX A

| Main Questions | Sub-questions / Statements |
|---|---|
| **Respondent Profile** | What is your primary relationship with sports? (Player, Coach, Referee, Spectator, Sports Analyst/Other Professional)<br>How many years have you been involved in sports?<br>At what level have you been involved in sports?<br>Which sport do you primarily follow or participate in?<br>What is your gender?<br>What is your age? |
| **Familiarity Questions** | How familiar are you with the topic of this questionnaire? (1-5)<br>How familiar are you with NOVA IMS (Portugal)? (1-5) |
| **Acceptance of Technology in Refereeing** | I am comfortable with refereeing decisions made entirely by technology.<br>I would trust an autonomous system to make in-game decisions.<br>Autonomous referees would increase my confidence in fairness.<br>Technology can be as reliable as human referees.<br>Human referees add subjectivity that makes the game more exciting. |
| **Impact on Viewing Experience & Game Flow** | Autonomous referees reduce human errors, improving viewing.<br>Technology would improve pace and flow of the game.<br>Relying solely on autonomous referees removes human emotion.<br>Autonomous referees make the game more objective and impartial. |
| **Strategic and Practical Considerations** | I would adapt my strategy if decisions were made by autonomous systems.<br>Autonomous referees minimize bias.<br>Technology-based referees less influenced by external pressure.<br>There should always be a human referee available to override.<br>Human referees add subjectivity that makes games exciting. |

| | |
|---|---|
| **Ethical and Social Implications** | Certain sports are more suited for autonomous referees.<br>Fully autonomous referees could work in all sports without harming integrity.<br>I would support phased introduction.<br>Concerned about lack of accountability.<br>AI referees should be tested in lower leagues first. |
| **Fan Experience and Engagement** | Prefer faster technology-assisted refereeing even if it reduces suspense.<br>I would watch more games if decisions were bias-free.<br>I would feel more engaged if decisions explained in real-time by AI.<br>More likely to support a team if AI refereeing ensures fairness. |
| **Open-Ended Questions** | What concerns do you have about autonomous referees?<br>Do you think autonomous referees will fully replace humans? Why or why not? |


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