

Innovation in Elite Refereeing Through AI Technological Support for DOGSO Decisions

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Abstract: Digitalization is driving social and economic change - in soccer, too. Artificial intelligence will increasingly solve problems and further intertwine the relationship between people and technology. Largely unexplored - but at the same time significant due to economic, psychological and sporting problems - are digital innovations in refereeing. Gottschalk et al. (2020) showed the potential for artificial intelligence and digitalization in refereeing. In a next step the researchers worked with the refereeing department of the German Football Association (DFB) to gain further insights for digitization in elite refereeing. As a result potential was identified for DOGSO decisions. The researchers conducted various interview rounds with elite referees of the German Football Association to identify all factors of human assessment influencing DOGSO decisions. The objective was to define a criteria system which can be evaluated by technology. As a result, more than 40 factors determining DOGSO decisions have been identified.

Keywords: Artificial intelligence, Digital transformation, Referee decision, Football, Decision-making, Trend Research

1. Introduction

Technological trends are influencing sports and enabling new economic potential (Cotterell & Vöpel, 2020). Digital transformation is a key driver. Multiple technological, digital and social drivers are shaping this development (Niestroj, 2020, Tewes & Tewes, 2020). Artificial intelligence (AI) will be one of the most effective change drivers in the future (Gerbert et al., 2020). In sports, a high amount of quantitative data is already used for performance profiles, and at the same time, serves for decision-making (Baumann, 2018). E.g., Bundesliga, the first German soccer league, and the German Football League (DFL) cooperate with Amazon Web Services (AWS) to exploit AI and machine learning (ML) potentials of soccer matches. For example, real-time analytics will be shown to viewers in the 2020/21 season (DFL, 2020).

However, a major problem in soccer still is misjudgment by referees. Three perspectives are essential to this problem:

1. Sporting perspective: Wrong decisions by referees influence the success of a team. Quitzau & Vöpel (2009) identify wrong referee decisions as the key random factors that can change the outcome of a match. The Video Assistant Referee (VAR) can prevent some obvious wrong decisions but does not completely eliminate them (DFB, 2019). Furthermore, wrong decisions by referees pose unevenly distributed disadvantages to teams (Quitzau & Henning, 2009). To this end, Downward & Jones (2007) show that referees tend to favor the home team in terms of awarding cautions and issue more cautions against the away team. In addition, referees make more disputed decisions in favor of the home team (Lovell, Newell & Parker, 2013).

2. Economic perspective: Wrong decisions by referees can influence the economic success of a soccer club. This is because media and marketing revenues or prize money are given to soccer clubs based on sporting success (DFL, 2016).

3. Psychological perspective: On the one hand, social pressure influences referees' decisions (Pettersson-Lidbom & Priks, 2010). On the other hand, players in professional soccer have to deal increasingly with pressure situations and psychological stress (Windmann, 2018, Raack, 2016).

Therefore, it is from a sporting, economic and psychological perspective important to minimize incorrect decisions by referees. Gottschalk, Tewes & Niestroj (2020) have found that the use of AI can help to solve this problem. Great potential for AI support exists in DOGSO decisions. This is because referees have to decide in a very short time whether an obvious goal-scoring opportunity was prevented by an offence – e.g., foul or hand play. However, only four written criteria are available for evaluating a DOGSO decision (DFB, 2020). These are not further specified in the Soccer Rules which makes it impossible to build an AI based algorithm to effectively support decision-making based on the existing criteria. Therefore, the following research question arises:

What factors must an AI algorithm consider for an effective and correct decision support in DOGSO situations?

To answer the research question, this paper relies on a qualitative research approach. The researchers conducted various interviews and discussion rounds with elite DFB referees. After three consecutive rounds, more than 40 factors were validated.

2. Background and Fundamentals

2.1. Innovation Potentials in Refereeing

On average, referees make over 200 decisions per game (Brand et. al., 2009). Referees should always pursue the goal of making decisions that comply with the rules. All decisions are subject to human judgment and are final (DFB, 2019).

To support human judgement, technology is now used at the elite level. The Goal-Line Technology (GLT) assists referees by verifying that the match ball has completely crossed the goal line (FIFA, 2014). Furthermore, the Video Assistant Referee (VAR) supports referees on the pitch during match-deciding scenes through TV images and is intended to prevent obvious wrong decisions by the referee (DFB, 2019).

Table 1: Potentials and limits for technology in refereeing. Source: Gottschalk et al., 2020

<i>Technology potentials</i>	<i>Technology limits</i>
+ Decisions that have to do with positions + Black-and-white decisions + Real-time data analysis + Contact identification during duels + Neutralization of psychological factors + Simplification of the referee's job + Detection of situations outside the referee's field of perception + Determination of an offside position + Evaluation of a tactical foul + Evaluation of DOGSO decisions + Detection of clear sanction violations + Use of analysis tools for match preparation + Monitoring the correct place of execution of the continuation of play + Kick-off, corner kick and throw-in decisions + Determining whether the ball is in or out of play + Identification of substitutes and substitute players + Detection of clear hand plays + Increasing fairness	– Decisions that require situational understanding – Discretionary decisions – Obtaining examples to train the AI – Training of image sequences – High manual effort – Evaluation of foul play – Attention to the basic motives of soccer – Empathic decisions – Match management of the referee – Advantage play and delayed whistle – Release of the game for continuation – Evaluation of the intervention in offside – Personal penalties for foul play – Time of review of a match scene – Assessment of punishable handball – Personality of the referee to manage a game – Verbal and non-verbal communication – Gray areas in hand play – Ultimate decision-making power is never technology – Risk of outsmarting AI – Ratio of effort and benefit

Further potential of innovation and technology - especially AI – is found for refereeing decisions that involve positions or are black-and-white decisions (Gottschalk et al., 2020). Referee decisions that require situational understanding and decisions with wide margins of decision - i.e., discretion, interpretation, or interpretation - are more difficult to support

by technology (Gottschalk et al., 2020). In the following, examples for positions and black-and-white decisions are given:

- Determining an offside position is very difficult for referees due to the scarcity of the situation. Although the intervention of an offside player is at the discretion of the referee, there is great potential for the use of AI (Gottschalk et al., 2020). An AI-based support algorithm can alert the referee to an offside position at the time of ball release.
- Black-and-white decisions include throw-ins, kicks, corner kicks, and the decision as to whether the ball is in or out of play. These decisions are based on well-observable factors and the decision-making process can be standardized. Further, black-and-white decisions are unambiguous.

Table 1 shows potential applications and limits for the use of technology in refereeing. In particular, the focus is on whether AI can provide support or comes up against limits. The referee's assessment of a DOGSO-situation can be supported by an AI-based algorithm (Gottschalk et. al., 2020).

2.2. DOGSO Decisions

The first part of this chapter presents the current rule for DOGSO offenses. In the second part, it is disclosed how referees make DOGSO decisions and how technology can support this process.

DOGSO decisions are summarized in the Soccer Rules under Rule 12 “Fouls and Unsportsmanlike Conduct”. Point 3 of this rule addresses disciplinary action. According to the rule text and corresponding to the offenses worthy of sending off, it says: Players, substitutes or substituted players who commit any of the following offenses are sent off:

- Preventing a goal or thwarting an obvious goal-scoring opportunity of the opponent by a handball offense (except for the goalkeeper in his penalty area).
- Preventing a goal or thwarting an obvious goal-scoring opportunity of the opponent, whose overall movement is directed towards the goal of the offender, by an offense punishable by a free kick (except for the regulations in the associated next section) (DFB, 2020, p. 80).

In particular, the following 4 criteria must be considered when making DOGSO decisions (IFAB, 2020, p. 112):

1. Distance between the offence and the goal
2. General direction of the play
3. Likelihood of keeping or gaining control of the ball
4. Location and number of defenders

Furthermore, three special cases are to be considered in addition for the referee (DFB, 2020):

- If a goal or an obvious goal-scoring opportunity is prevented by a player's handball, the referee shall send off the player regardless of where the handball occurred.
- If the referee judges an offense in the penalty area to be a DOGSO offense - but this offense was ball-orientated - the fouling player shall only be cautioned; if it is not a ball-oriented offense, the fouling player shall be sent off.
- If a goal or an obvious goal-scoring opportunity is thwarted by the interference of a player or substitute, the player or substitute shall also be sent off.

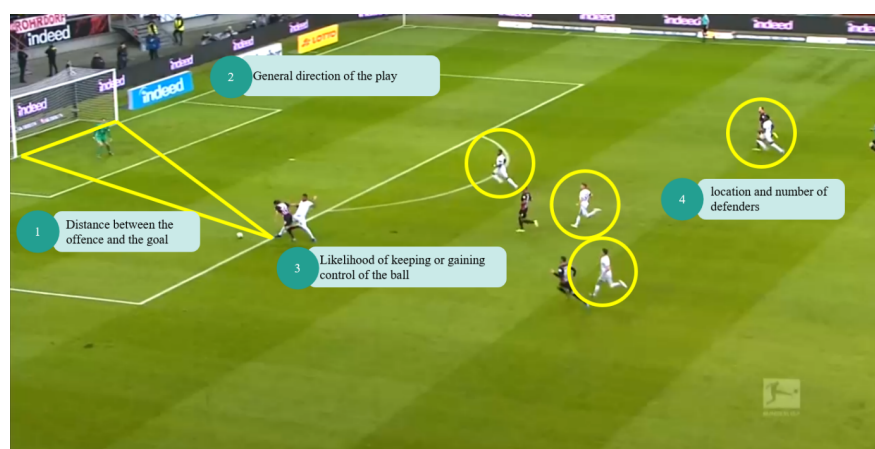


Figure 1: 4 Criteria for DOGSO decisions

Source: Screenshot taken from Bundesliga match day 10 of the 2019/20 season, 02.11.2019

The 4 criteria for judging a DOGSO offense are not further specified in the Soccer Rules. For this reason, the referee must use a great deal of human judgement and discretionary authority to decide on DOGSO offenses. In addition, the 3 special cases described above make the referee's decision regarding DOGSO offenses even more difficult. Figure 1 shows the 4 criteria according to the Soccer Rules using an example video screenshot at the moment when a referee must evaluate these criteria.

Referee decisions are difficult in any way, as they have to be made from only limited perspectives within fractions of a second (Brand, Plessner, and Schweizer, 2009). In this context, only the referee's subjective and selective perception serves to make decisions on the pitch (Feuerherdt, 2018). Referees make decisions as a result of 4 steps (Paasch, 2019). After referees perceive a situation, they assess it and establish a fact. Then, the referee applies a rule and finally implements it. It is scientifically proven that referees are influenced by biases. Examples include:

- Home crowd's noise (Nevill et al., 2002)
- Players' reputations (Jones et al., 2002)
- A team's origin (Messner & Schmid, 2007)
- Own prior decision (Brand et al., 2006; Plessner & Betsch, 2001)

An AI-based decision algorithm for DOGSO would have to evaluate the 4 criteria of the Soccer Rules described above. There is already technology in use that measures and analyzes parameters of a team's attack (DFL, 2020). Specifically, the xGoals technology uses event and position data to determine how likely a player is to score in a situation by assigning a probability value between 0 and 1. Data such as the angle of the shot to the goal, the distance of the shooter from the goal, speed, goalkeeper position and defender position are used to calculate the probability value. This data is compared to 40,000 records in the Bundesliga database so that an AI-based decision algorithm can output a probability value. This tool serves soccer teams for the purpose of analyses or provides spectators with an enhanced experience during the soccer match. However, a similar tool could be used for DOGSO decisions. This is because tactical foul plays or DOGSO offenses also require the identification of position and event data (Gottschalk et al., 2020).

3. Research Methodology

To be able to apply an AI-based technology for DOGSO decisions, the 4 criteria from the Soccer Rules described in Section 2.2 must be broken down in a way that the information can be understood and evaluated by a machine. To date, DOGSO decisions have been based on human perception and experience. Hence, the 4 criteria have been designed only for this purpose. Therefore, all measurable factors that referees must consider in DOGSO situations have to be collected. The following chapter presents the research methodology. The overall objective is to validate and calibrate this criteria system so that a model for the prediction of DOGSO probabilities is precisely set up.

3.1. Methodical Approach

The research design is based on 3 different studies that build on each other. For this, the scientific methods of secondary data analysis and group interviews are used. These are referred to below as U-I, U-II and U-III.

U-I is comprised of the construction of a complete prototype criteria system for the evaluation of DOGSO decisions. Here, video scenes of DOGSO decisions are analyzed. Based on these scenes, a first full set of relevant criteria can be identified. This criteria set builds on the 4 initial criteria of the Soccer Rules. Specifically, by evaluating the video scenes the initial 4 criteria are further differentiated until they can be measured and evaluated by an AI-based algorithm. Hence, it is necessary to define measurable characteristics for each criterion, like speed, distance, or position. This procedure results in a decision tree that contains, in addition to the 4 criteria of the Soccer Rules, subordinate, or "sub-criteria", and measurable characteristics of each sub-criterion.

U-II builds on U-I. U-II aims to validate the criteria system with experts. The experts involved in DOGSO decisions are referees from the German elite refereeing system. The referees are given insight into the developed criteria system during group interviews. In the interview, the referees assess the completeness of the system as well as each criterion for its influence on the probability of a DOGSO situation. The referees also can name additional criteria if necessary. At the point when no changes are made to the criteria system by the referees, the investigation is complete. This is because theoretical saturation is reached after this step (Strübing, 2008).

U-III finalizes the criteria system. After U-I and U-II have developed and validated a criteria system, it must be finally confirmed. The expertise to confirm the developed criteria system is held by the sporting management of the DFB refereeing. The criteria system was made available to the sporting management. After the confirmation of the criteria system by the sporting management, U-III is completed.

3.2. Sampling

U-I includes 66 video scenes from the 1st to 3rd Bundesliga. The video scenes are potential DOGSO decisions. The decision is either no sanction, warning or sending off, depending on the assessment of the referee in the respective match. The analysis of the video scenes results in a criteria system: 4 criteria on the first level based on the Soccer Rules, 8 criteria on the second level, 9 criteria on the third level, 2 criteria on the fourth level and 3 - 4 measurable characteristics per criterion on the last levels. To determine the first criterion according to the Soccer Rules 'distance between the offence and the goal', a playing field which is divided into 17 zones is applied.

For U-II, expert interviews are conducted in a group with 13 referees of the 1st to 3rd Bundesliga and with 3 assistant referees of the Bundesliga. A group interview consists of 3 to 4 participants and has a time frame of 60 minutes.

U-III includes the confirmation of the criteria system by the sporting management of the DFB. This is comprised of 6 members - consisting of the Sporting Director, Head of Coaching, Head of Qualification & Training, Head of Technology & Innovation, Coordinator Referee Assistants and Head of Coaching 2nd Bundesliga.

4. Results and Interpretation

In the following, the results of the research are presented. Results of the research are more than 40 factors or criteria resp. influencing DOGSO decisions. Chapter 4.1 includes the description of the model. For a graphical representation of the model, please refer to the Appendix. Based on this, the derivation of recommendations for action follows in chapter 4.2.

4.1. Factors Influencing DOGSO Decisions

1. Distance between the offence and the goal

The referee must assess the situation when the foul occurs and not at any earlier or later point in time, otherwise, the factual situation changes significantly.

The referee must decide whether the place on the playing field where the offense happened indicates a clear scoring opportunity. Therefore, the playing field was divided into 54 zones. The zone of the offense is determined by the distance and angle to the goal. Figure 2 shows the division of the field into these zones. In particular, the zones at the opponent's goal must be very small and become larger with increasing distance from the opponent's goal. This is because the DOGSO probability increases the closer and more central to the opponent's goal the offense occurred.

2. General direction of the play

In particular, the general direction of the play is related to the style of play e.g., a dynamic attack, of the attacking team. Essential for the evaluation of this criterion is whether the general direction of the game indicates a dynamic attack or even a counterattack, or a rather static attack. There are 5 sub-criteria to assess this question:

- 2.1. Speed of the fouled player at the time of the foul. The speed of the player is to be differentiated between sprinting, trotting, walking and standing.
- 2.2. Speed of the fouled player's teammates. Here, the same characteristics can be used as for the first sub-criterion. For these two sub-criteria, a high speed of the player at the time of the foul is more indicative of a dynamic attack than a low speed.
- 2.3. Velocity or the speed of the ball. A high speed of the ball may indicate a dynamic attack. The speed of the ball can either be equal to the speed of the player with the ball or faster or slower than it.
- 2.4. Running paths of the attacking players.
 - 2.4.1. On the one hand, the running path of the player with the ball and, on the other hand,
 - 2.4.2. the running paths of the other players of the attacker's team. If the running paths of the players lead straight towards the opponent's goal, a dynamic attack takes place. If the running paths do not point directly towards the opponent's goal but focus on the goal line or do not lead towards the opponent's goal at all, the probability of a dynamic attack is correspondingly lower.

- 2.5. Type of possession of the ball by the attacking team. This is primarily about the duration of the ball possession of the attacking team. There are 3 different types of possession. The possession can already be over for several meters, it can have taken place directly through a change of possession or it cannot be present at all.

3. Likelihood of keeping or gaining control of the ball

The probability to stay in possession of the ball or to come into possession of the ball has an influence on the DOGSO decision. From a technical perspective this rule is separated into two criteria or let's say scenarios:

Scenario 1: Likelihood of keeping control of the ball

In this case, the attacking team owns the ball at the time of the offense. Essential to determining the probability of retaining possession of the ball is determining the quality of ball control. To measure ball control, 5 sub-criteria must be considered. The first 2 sub-criteria concern the ball position.

1. The ball position to the ground at the time of the defending team's offense must be determined. The ball position to the ground consists of 4 different characteristics. Either the ball is on the ground at the time of the offense, at the player's waist level, at the player's head level, or above the player's head level.
2. Position of the ball in relation to the player. This indicates whether the ball is in direct control by close ball control, whether the ball is close to the attacking player, or whether the ball is far away from that player at the time of the offense.
3. Relation of the attacker's speed to the ball. A distinction is made between the following characteristics. In the first case, the ball and the player have a similar speed, secondly, the ball is faster than the player or thirdly the player is faster than the ball. Especially in the second case, the question is whether the player can still reach the ball before it would leave the field of play. Accordingly, the decreasing speed of the ball, the boundary lines of the playing field and the speed of the player must be considered.
4. Number of playable teammates. This sub-criterion is included because if the number of playable teammates is high, the probability of keeping possession of the ball is considered higher for the team. To determine the number of playable teammates, the following factors must be taken into account: the position of the players, the running paths of the players, the speed of the players and the space available to the players.
5. The attacking player is directly involved in a duel by other defenders at the time of the offense. This sub-criterion aims to determine the pressure on the attacking player. For this determination, the relation of the speed of the defenders to the attacking player and the distance of the defending players to the player with the ball must be checked.

Scenario 2: Likelihood of gaining control of the ball

In this case, the attacking team does not yet have possession of the ball. A typical case, for example, is when an attacking player hits a high pass from the sideline towards another attacker positioned in the middle of the penalty area. This attacker, before he can take possession of the ball, is fouled by a defending player. Therefore, the question is whether this player would have gained possession of the ball if the defending team's foul had not occurred.

The determination of this probability is done in two steps. First, check whether the attacking player would reach the ball before it left the field of play. If so, the second question is to determine whether the attacking player would then be able to control the ball.

1. In this Scenario the position of the attackers, running paths of the attackers, speeds of the attackers, position of the ball, trajectory of the ball and speed of the ball must be considered.
2. In addition, if the offense of the defending team is a handball, the further trajectory of the ball must be determined. This is because the difference to the first Scenario is that the trajectory of the ball would be suddenly stopped by the handball.
3. To make the prediction of the trajectory of the ball after a handball, the time and place of the handball and the distance traveled by the ball at the time of the handball must be taken into account. In terms of the time of the handball, it makes a difference whether the defending player commits the handball just before the attacking player gains possession of the ball or immediately after the pass to that player has been made.
4. Further, it is about the possibility of the attacking player to control the ball after reaching it. For this, the following influencing factors must be taken into account - the height of the ball, the spin of the ball, the speed of the ball and the orientation of the attacking player to the ball.

4. Location and number of defenders

The fourth criterion considers only the defending team. The decisive factor here is the possibility of an intervention by the defending team at the time of the offense. It is important to note that the defender committing the foul or handball may no longer be considered here. The following criteria differentiate between the possibility of intervention by the goalkeeper and by other defending players. Separate consideration is necessary since the goalkeeper is the only player who, according to the Soccer Rules, can play the ball with his hands inside his penalty area.

1. Goalkeeper's position to measure the ability to intervene. It must be measured whether the goalkeeper is between the ball and his own goal, to the side of the ball or behind the ball.
2. Goalkeeper's line of sight to the ball - this can either be directed towards the ball or not directed towards the ball.
3. Vertical position of the goalkeeper. A distinction has to be made whether the goalkeeper is lying on the ground or standing upright facing the striker.
4. Goalkeeper's probability of reaching the ball before the attacking team. This criterion depends on 3 other sub-criteria.
5. Movement of the goalkeeper
6. Movement of the attacking players
7. Movement of the ball
8. Concerning the players, running distances and speeds must be measured. To determine the movement of the ball, its height to the ground must also be detected.
9. Goalkeeper's room for maneuver. If the goalkeeper can use his hands to intervene, the DOGSO probability is lower compared to the situation where this is prohibited to the goalkeeper due to leaving his penalty area. Furthermore, it must be checked whether the goalkeeper is allowed by the rules to play the ball a second time. For example, he may be prohibited from doing so after taking a goal-kick or free-kick.

In addition, the possibility of intervention by the defending team must be measured. This must be given before the attacking player has a high probability of scoring a goal. Basically, 4 sub-criteria are distinguished here.

10. Position of the defenders. It is important to recognize whether defenders are between the ball and their own goal, in a staggered line between the ball and their own goal, or behind the ball. For example, if the defenders are only behind the ball, the possibility for the defending players to intervene is significantly reduced.
11. Running path of another defender crosses the running path of the attacker before a clear scoring opportunity. The goal is to determine the defender's ability to battle for the ball against the attacker. Again, the movements of the defender and attacker, broken down into running paths and speeds, are to be measured here.
12. Running path of another defender makes it possible to reach the ball before the attacker. In contrast to the previously listed case, this is not about tackling, but about intercepting the ball. In addition to the movement of the defending players, the movement of the ball, divided into ball speed, trajectory and ball height to the ground, must be analyzed. Analogous to the goalkeeper's ability to intervene, the defending players' room for maneuver must also be examined. For this purpose, it must also be checked whether the defender is entitled to play the ball a second time.

5. Other categories

The research also shows that in addition to the 4 criteria from the Soccer Rules, further factors must be considered that cannot be directly mapped into the 4 primary criteria:

1. Ball-oriented offenses in the penalty area are only punished with a warning. However, the assessment of the DOGSO decision remains the same, but in this case, there is a reduction of the sanction towards the fouling defender.
2. The attack of the attacking team's has already been completed by a goal kick and a defending player commits a punishable handball on the goal line. If the ball would have gone into the opponent's goal without this handball, the hand-playing defender must be sent off. To evaluate this case, the trajectory of the ball, the speed of the ball, the position of the goalkeeper, the positions of other defenders and the position of the attackers must be analyzed. The position of the attackers must be recorded to determine whether players can evade from the ball if they were previously in its trajectory. For this purpose, the ball speed and distance of the attacking players to the ball have to be measured.

Further factors, which are not included within the 4 criteria refer to characteristics of players. Here, individual skills and abilities of the players, maximum speeds of the players or degrees of exhaustion can be considered.

4.2. Recommendation for Action

The research shows over 40 relevant factors that referees need to consider to make a DOGSO decision. While this provides a complete picture of all possible factors, there are additional steps that need to be taken before technology can be used to assist referees in DOGSO decision-making.

Specifically, the measurable characteristics of the criteria have to be specified in detail. For example, research has shown that a player's speed has an impact on DOGSO decisions. However, it is to be defined at which exact speed a player is walking, trotting, or sprinting.

Further, it is necessary to estimate the exact influence of each factor or criterion resp. on the DOGSO probability. For this purpose, the entire criteria system must be calibrated. Specifically, each influencing factor must have a weighting, which contributes to the overall DOGSO probability. To calibrate the system, further expert interviews with elite referees are recommended. In a further step, statistical methods are to be applied to finalize and test the model calibration.

The final goal is to develop an AI-based model that can be applied in practice. However, before a new technology can be applied in practice, it must be tested extensively. A test phase should be accompanied by researchers, developers and the sporting management of the DFB so that finally a system can be implemented in soccer that is reliable.

5. Conclusion

In the multi-million dollar business of soccer, important decisions are made. Referees play an essential role in this environment through their decisions during a soccer match. Wrong decisions by referees are a major problem in this context from a sporting, economic and psychological perspective.

It is already evident that technology can support referee decisions. Existing technologies like GLT or VAR have a track record in supporting referees and minimizing wrong decisions. Further use of technology is well applicable where referees make unambiguous - so-called black-and-white - decisions or decisions that have to do with positions. For this reason, DOGSO decisions can be next to be supported by technology.

This paper had the goal of identifying all criteria of DOGSO decisions that can be measured and evaluated by an AI-based model in the future. The result of the research is comprised of over 40 factors influencing the referees' decisions in practice. Due to the high number of factors for DOGSO decisions, it is evident that referees in practice cannot consider all influencing factors in detail within a short period of time. Therefore, there is a great need to use the identified factors to develop a technology that supports the referee.

The results of this paper provide the basis for further research. In subsequent research, the exact calibration of the model needs to be determined. Furthermore, the measurable characteristics of the criteria need to be determined. Before an AI-based decision model can be applied in practice, an extensive test phase is also necessary.

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