

OPERATIONS RESEARCH IN REFEREE ASSIGNMENT IN THE FIFA WORLD CUP

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Abstract: Football is the most watched sport and a billion-dollar industry. This sport like any other has a lot of inconsistency problems like scheduling, recruitment, optimization, ticketing that can be solved using quantitative techniques. With the increase in the ability to gather information about all kinds of aspects of the sport using computers applying OR is becoming really lucrative for team managers as well as tournament hosts. Our research paper tackles one such problem of referee assignment in the FIFA world cup with the objective of finding a fair referee for every match.

Index Terms – Football, FIFA, Referee Assignment, Algorithms, Hungarian Method.

I. INTRODUCTION

Football – the English sport that became a billion-dollar industry. A recent article by the New York Magazine showed an excerpt from the conversation between Jürgen Klopp, Liverpool's Manager and Ian Graham, the research head. Graham was explaining how Klopp's previous team Dortmund lost by score and not by any other parameter. However, he did this even without even watching a single second of the game. He analyzed the entire game sheerly based on statistics of ball possession, shots taken, successful shots, etc. He could successfully paint a perfect picture of the entire game using numbers and mathematical equations. And during this conversation he pitched his idea about relying on statistics to recruit new players. He used his own, self-modelled database that tracked over 1,00,000 players all over the world. The fruit of this was perhaps Liverpool's best season in the longest while. They lost only one match in the entire season, the final. This is only one of the few instances where Operations Research helped bring about dramatic improvements in football. Football is one of the most viewed sports in the world with leagues spanning months and competition that is ever increasing. Thus, optimization is required in every single area whether it comes to recruiting, ticketing, scheduling or even referee selection. Management sciences is the study of problem solving and decision making in almost everything that a human does. This has a strong impact in the business, management and economic sphere. This field came up as an extension to mathematics and is one of the most essential applications of it. The results are obtained to make a practical impact by implementing them in ways such as lower cost, seamless administration, identifying future paths, analyzing strategies adopted and their deviations so they can be rectified. The study of management sciences is essential to the extent that an organization cannot run in a proper manner unless methods of management sciences are implemented; otherwise the objectives will not be attained as efficiently as they would have been able to.

Operations research has a huge scope of changing the industry further and the capabilities are slowly being realized by people who will be affected by the outcomes of the analysis using OR methods. Simulation is used to find out the results of a game, Linear programming is used to reduce the costs and ensure better allocation of resources, Transportation method is used to find better allocations for players and when they should or should not play, Allocation method is used to find out the most optimal strategy of a team and many more methods are used in different ways to obtain useful results.

This paper is focused on using operation research theories to perform better allocation of administration in a football match. This method if used will make the work of higher administration easy in allocating different referees and other essential employees to locations and matches they need to be a part of. This will greatly reduce costs and provide better allocations so that the referees can be used with most efficiency.

II. OVERVIEW OF THE INDUSTRY

Football in its current form originated from England. However different forms of this game have been seen in ancient history of Greece, Rome, China and Japan. What started as a small game quickly gained popularity and was made an official sport in 1863 as the Football Association was formed in England. This sport then went international with the creation of FIFA (Fédération Internationale de Football Association or International Federation of Association Football) in 1904. What started as a small sports association with 10-member nations now became a 221-member nation mammoth. The FIFA world cup is now one of the most viewed international sporting events in the world. Giving rise to many other leagues like the infamous Champions league. Football is now a multi-billion-dollar industry with league holders like FIFA making billions of dollars from licensing, ticket sales, merchandise and more.

Applications of Operations Research in football:

Since football became such a huge sport optimality in terms of handling these events became an important concern. Following are the major problems in football that are tackled with operations research:

The problem of scheduling is the first problem in hosting football events. Scheduling football matches has a lot of variables that must be considered which include the geographic location, weather, home or away matches, etc. A great example of this would be the scheduling methods used Scheduling Chile's Second Division Soccer League. They even took into account the major events happening in a city if there was a home match to be held in that city.

A famous quantitative algorithm used is the "Round- Robin Tournament Method". This basically ensures that each contestant (in this case team) competes against everyone in the tournament.

The second problem is referee assignment. A high stakes competition will employ a large number of referees for their tournaments. These referees are selected from all parts of the world to maintain fairness and make sure the referees are not biased. In order to do that many competitions, use assignment algorithms to optimize the process. Once the algorithm is built they can keep changing inputs and variables to their desire. The variables that can be taken under consideration might be fairness, cost, teams playing the match, past matches, etc.

The third problem arises on the side of the teams. Efficiency in terms of victories and winning potential allows teams to decide about future investments and where they are lacking. It lets other researchers find out which teams are the most efficient and suggest their methods to the failing teams. It can help in deciding many decisions like whether they should hire more talent or change strategy. Constraints may include the budget, the country if it is a nation-based cup, etc.

Another problem would be ticket allocations. This is basically deciding how to allocate the seats in tiers to maximize profit and reduce left over seats. This takes into account how much people are willing to pay for a good seat, the demand for those tickets, the city the match is held in, etc.

III. RESEARCH OBJECTIVES

1. To understand the application of OR in the field of football referee assignment.
2. To find an optimal method of referee assignment using OR.
3. To elaborate on the significance of quantitative techniques to make football fair and to create a more equal platform for the teams.
4. To outline the importance of referee assignment in order to make matches fair and unbiased.
5. To describe the use of algorithms in the decision making of various types in football matches.

IV. RESEARCH METHODOLOGY

Since the time of evolution of Operations Research, especially in the field of sports, many people have tried to optimally utilize different strategies and tactics in order to have the best position in the game. Today sports have also become a major part of big businesses. Forbes valued the Major League Baseball teams at almost over \$15 billion, while the Yankees alone had a worth of \$1.7 billion. When such high values are involved too, Operations Research can be counted on in order to make better decisions. Be it finding the most optimal batting order of a baseball team (Freeze,1974) or helping in team selection (Boon and Sierksma, 2003), operations research has been able to find out the most favorable solutions to different problems.

In our Research paper, we are looking into the problem of non-discriminatory assignments of referees during the FIFA World Cup Matches. The assignment of a referee is an important task as the correct assignment can help in eliminating biasness on the part of the referee. In order to avoid this unfairness, we have taken the study of Assignment Problems.

Assignment/Allocation problems involve the distribution of resources among competing alternatives in order minimize total costs or maximize total returns. With the help of the Hungarian Assignment Method we have taken the relationship between the number of matches played and the cost of assigning a referee based on their fairness ratings.

V. LITERATURE REVIEW

Over the last decade, professional football has gained extreme popularity around the world. This surge of popularity can be attributed to various factors such as increased investment in football clubs, players, stadiums and coaches. As well as rise in expenditure towards advertising, merchandising and marketing of football clubs. Internationally, the viewership of the sport has increased with leaps and bounds thanks to the simultaneous increase in availability of resources to access technology. Every year the clubs invest and reinvest in their squads to improve their field performance which in turn helps boost the interest of supporters and sponsors in the club.

India has been a dormant football giant, which has only recently woken up and is now picking up pace and moving towards a booming football industry. India has now won the hosting rights of the FIFA U-17 Women's World Cup 2020. This growing popularity has attracted many international clubs and leagues to invest and explore India as one prospect to expand their presence. Multiple foreign clubs are collaborating with local leagues like the Indian Soccer League (ISL) and the I-League clubs to showcase their commitment towards football's presence in India.

(Srivastav, 2019) the use of Operations Research in football is vast and unprecedented. Like match scheduling, referee allocation, strategy formulation and match forecasting. There are quite a few engaging papers on the application of Operations Research (OR) in the sports and specifically the football industries.

(Günneç & Demir, 2019) the sports industry especially the football industry today, are valued at multiple billions of dollars. People follow national as well as international football, there is competition among countries to host international football tournaments like FIFA. Football clubs make colossal investments in players, coaches, stadiums, merchandise, management, marketing, advertisement and broadcasting amongst others. Another method to attract audience is by making use of game schedules, football fans prefer matches played in local stadiums, and broadcasting companies want to find schedules that would maximize their advertisement revenues.

(Hariyani, Malladi, Mehta, Dedhia, & Bhutka, 2018) Federation Internationale de Association (FIFA) makes extensive use of OR techniques like the basic linear and nonlinear linear programming tools for determining the audience and ground arrangements and complex models like stochastic programming and a continuous time Markov Chain to determine different social anomalies and the economic and geographical conditions that may or may not affect the Federation.

(Raja & Morrow, 2007) The paper uses the Malmquist non-parametric technique to judge and measure the efficiency and productivity in performance of clubs in the English Premier League. This is derived from the Data Envelopment Analysis (DEA) linear programming approach, with Canonical Correlation Analysis (CCA) being used to ensure the cohesion of the input-output variables. The paper concludes that though clubs operate close to efficient levels for the assessed models, there is barely any technological advance in their performance in terms of the displacement of the technological frontier.

(Badmus, Akinwande, & Ukaegbu, 2017) This study aims firstly, at examining if any English Premier League (EPL) club could maintain steady efficiency during the period of (2005-2015) and secondly, at identifying the most efficient club(s) within the same time period using Data Envelopment Analysis (DEA). The paper concludes that only one club (Aston Villa) was able to maintain the same level of efficiency over the research period. The result also confirms that efficiency is not an absolute privilege of national league champions or the big clubs. However, this inefficiency is mainly observed due to waste of productive resources among EPL clubs.

(Coleman, 2012) Identifying the "Players" in Sports Analytics Research – this paper sheds light on the various published articles, journals and research papers on the topic of sports analysis research. The history of SA goes back around 50 years and has recently observed a dramatic rise amongst the level of interest in sports analytics. The industry was mainly untapped in terms of scholarly research and had barely begun efficient usage of existing research. The paper examines around 140 journals in operations research, statistics, applied economics and applied mathematics and has also identified 1,146 articles that reference the application of OR in sports. The conclusions provide an idea about the size and nature of SA research and offers certain perspective on the field parameters.

(Haas, 2003) Productive efficiency of English football teams—a data envelopment analysis approach; this paper studies the efficiency of English Premier League Clubs during the 2000/2001 season. It uses a deterministic Data Envelopment Analysis Approach. It investigates how close to their potential the clubs under observation played. It measures the productive efficiency of the teams and weakness of individual teams. This is done through careful consideration of all limitations and assumptions of various Operations Research models and their various combinations of inputs used.

(Zambom-Ferraresi, et al., 2017) Sports Results Measurement and Efficiency in UEFA Champions League – the paper analyzed the sports technical efficiency of the UEFA Champions League (UCL). The analysis was conducted on the data of the teams that played during nine seasons (2004/5 to 2012/13). Data Envelopment Analysis (DEA) which is a deterministic non-parametric frontier method was used to conduct this analysis, whereby constant return to scale and variable return to scale has particularly been applied. They analyze the efficiency in UEFA Champions League by considering a longer period of time and applying the coefficients of revenue distribution as sporting results management. The paper has three findings – high levels of inefficiency in UCL; clubs can be efficient but lose their efficiency simultaneously which is why they cannot maintain efficiency over the season; inefficient usage of resources.

(Peña & Touchette, 2012) A network theory analysis of football strategies – the paper uses some tools from network theory to help explain the strategy of football teams. It used data made available by FIFA during the 2010 World Cup and constructed a weighted and directed network for each team where nodes correspond to players and the arrows to passes. The resulting graph helped to identify the play pattern, determine hot spots on the field and identify potential weak points. It also helps determine the relative importance of each player in the game.

VI. RESULTS AND DISCUSSION

European football is one of the most popular sports played in the world. Thus, it becomes imperative that a sport of such large magnitude should resolve the complications it faces with the help of systematic and detailed Operations Research. During FIFA World Cup, one of the major problems that the football association faces is the non-discriminatory assignment of referees for the matches. During the World Cup each game requires a total of four referees. They consist of a center referee, two assistant referees and a fourth referee who is responsible for keeping a track of all the bookings and substitutions that occur during the match.

In our paper we shall be taking only the assignment of the center referee as the subject of study. The assignment of center referee plays an important role in football games because outcome of the game can sometimes get affected due to biasness or unfair conduct on the part of a referee. In the paper we have taken benefits of use of Operational Research in the assignment of referees during the final tournament, where 32 countries play against each other in two phases. First phase is the group phase, where 8 groups of 4 teams each compete against each other to get the top 16 teams.

The top 16 comprise of the top 2 teams from each group. The group phase is followed by the knockout phase.

During the FIFA World Cup of 2018, 36 referees along with 63 assistant referees were selected from 6 different confederations from around the world on the basis of their nationality. However, while assigning matches to the referees there are a few restrictions/constraints that the football federation had to face. They are:

1. Ensuring that the assigned referee of a game, is not from the same nation or federation of the two teams taking competing in the match, so as to reduce the chances of any biasness that a referee may have towards its own nation or federation.
2. Assignment on the basis of location. During the group phase of the tournament there were four locations at which approximately three different matches are being played during the same day. Thus, while assigning the referees the organizers had to take into account the fact that one single referee cannot be assigned to multiple matches happening at the same time or even happening on the same day.
3. The cost of travelling, stay and fee paid in totality needs to be also kept as low as possible to ensure that there is no undue wastage of money.

Thus, in order to assign referees, we have suggested the use of the Hungarian Assignment Method. In this method we have taken into consideration the number of matches being played with respect to the cost of assigning a referee based on their fairness rating and taking into consideration all the above stated constraints. Since there are three matches being played each day at any of the four different locations, we shall make a team of four referee groups for each of the four different locations. Also, at least one referee from each confederation is present in each group, with the exception of the Oceania Football Confederation which only consisted of two referees (as only two referees were shortlisted by the Federation),

During the Group phase of the tournament, the match schedule is decided prior to the beginning of the tournament on the basis of the round-robin approach. During the group phase 48 matches are played amongst the teams. We can thus allot the referees using the Hungarian Allotment Method by making a matrix with the number of matches played and number of referees on the basis of their cost that is the price charged by each referee on the basis of their status and rating.

However, after the group phase has come to an end, the number of referees get reduced to 20. During this phase two matches are played each day. In this phase the matches are decided on the basis of the outcome of the previous match. Thus, the allotment of referees has to take place after the outcome of each match. This same procedure can be used by the federation for the quarter finals, semi-finals and the final also. Thus, with the help of HAM they can have an optimal allocation of referees while minimizing their cost.

VII. CONCLUSIONS

From the previous researches carried out, we can conclude that Operations Research was used very effectively and extensively in FIFA world cup 2018. The entire FIFA world cup 2018 was carried out very smoothly with negligible or zero error. It also helped to a huge extent in order to reduce overall costs and plan out and the allocation of referees, designing of the matches etc., extremely efficiently. Even though there are limitations to the use of Assignment Problems, its advantages overcome them all. This shows us that assignment problem is an extremely diverse method and can be used in numerous fields to find the most effective and optimal solutions.

VIII. LIMITATIONS

There are a few limitations which we need to consider when we applied Assignment Problem in the field of football. Few of them are mentioned below: -

- There is a lack of previous knowledge in the field of operation research in football, therefore it is not a comprehensive study.
- The data provided cannot be totally reliable since the field is still not fully explored therefore the literature reviews had to be narrowed down too.
- Being new to the field of Operations research, we did not have the extensive pre-requisite knowledge of the study and therefore could not explore more dimensions and other methods on this problem.
- Since the football industry is competitive in nature, none of the teams or leagues voluntarily disclose the details of the methods and tactics they use, therefore our paper has lesser depth as to which other methods can be used.

IX. ACKNOWLEDGMENT

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g”. Avoid the stilted expression,

“One of us (R.B.G.) thanks...” Instead, try “R.B.G. thanks”. Put applicable sponsor acknowledgments here; DO NOT place them on the first page of your paper or as a footnote.

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