



INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X

Impact factor: 4.295

(Volume 5, Issue 5)

Available online at: www.ijariit.com

Understanding, comparing and evaluating the use of Operations Research in the gaming and sports industry

Vivek Ahuja

vivekahuja.apple@gmail.com

Narsee Monjee Institute of Management
Studies, Anil Surendra Modi School of
Commerce, Mumbai, Maharashtra

Zinatra Dsouza

zinatra2000@gmail.com

Narsee Monjee Institute of Management
Studies, Anil Surendra Modi School of
Commerce, Mumbai, Maharashtra

Uchiet Daas

uchietdaas18@gmail.com

Narsee Monjee Institute of Management
Studies, Anil Surendra Modi School of
Commerce, Mumbai, Maharashtra

Vatsal Nyati

vatsalnyati2000@gmail.com

Narsee Monjee Institute of Management
Studies, Anil Surendra Modi School of
Commerce, Mumbai, Maharashtra

Vedant Bokadia

vedantbokadia@gmail.com

Narsee Monjee Institute of Management
Studies, Anil Surendra Modi School of
Commerce, Mumbai, Maharashtra

Urja Shah

urjaanilshah@gmail.com

Narsee Monjee Institute of Management
Studies, Anil Surendra Modi School of
Commerce, Mumbai, Maharashtra

ABSTRACT

This research paper drills deep into team sports and sports management. Highlighting those aspects of the sports industry that extensively use Operations Research or have the ability to incorporate Operations Research in the future to improve their decision making as well as efficiency. This paper has been written after comprehensively evaluating existing Research Papers.

Keywords— Sports analytics, Scheduling, Stadiums, Tactics and Team Development

1. INTRODUCTION

1.1 What is Operations Research?

Operations research (OR) is a logical method of problem-solving and decision-making that is helpful in the management of organizations. In operations research, difficulties are broken down into basic workings and then solved in defined steps by mathematical analysis. (Rouse, 2019)

1.2 Advantages of Operations Research

- Improved Decision Making:** As the above example shows, operations research techniques can take a muddle of factors and numbers and reduce them to simple formulas. These formulas will find the optimal solutions within the constraints of the problem.
- Better Control:** OR techniques have given managers the tools that deliver better direction and control over subordinates. A manager can use OR approaches to set up performance standards for employees and identify areas that require improvement.
- Higher Productivity:** An important use of OR is the capability to identify optimal answers. A few examples are finding the best inventory combination, optimal use of manpower, most desirable use of plant machinery and most-producing marketing campaigns.
- Better Departmental Coordination:** After the optimal results from OR analysis are shared with all the departments, everyone works together toward the common goal. For example, the marketing department might synchronize their efforts with the schedules out by the production supervisor.

Operations research is important because it is a useful tool that can help in solving complex problems under uncertainty. In business, very few things are of certainty, and managers must often make decisions based on their instincts rather than being able to use reliable data. Operations research techniques fill this void with methods that quantify issues and give business managers a better basis for making decisions. (Woodruff, 2018)

2. OVERVIEW OF THE GAMING AND SPORTS INDUSTRY

2.1 Operations Research in Sports

The scheduling of sports competitions has as of late been getting a lot of consideration in the operational research literature. This exploration considers the planning of competitions that happen on several venues not related to any of the members. It was spurred

by the solicitation from a lead trainer of a major college football team to aid the improvement of a preparation plan for intra-squad team competitions on different drill stations. An integer objective program is created to develop a schedule that fulfills different conditions. (Timothy L Urban, 2011)

Tactics and strategy

Over time researchers have found multiple ways to optimize the strategies for different sports. For example Freeze (1974) who used a simulation to find the best batting order for a baseball team, Boon and Sierksma (2003), they produced a decision support system to help football coaches and managers assess contributions of particular players to their teams, hence helping not only in team selection but also in scouting and purchasing new players, Scarf and Grehan, (2005) determined the optimal route to choose while cycling. A tactical example of OR is the decision of whether a team should run or pass in a game of American football, this can be solved using Linear programming.

Scheduling

Scheduling competitions is another important application of OR in sports as Sports teams need schedules that satisfy different types of constraints. Optimization of such a Timetable is done using several Operations research techniques.[1]

Forecasting

It is the process of making predictions of the future based on past/present data and most commonly by analysis of trends. The unique contribution that OR can continue to make to forecasting is through developing models that link the effectiveness of new forecasting methods to the organizational context in which the models will be applied. In many real-life sports games, spectators are interested in predicting the outcomes and watching the games to verify their predictions. [2] Traditional approaches include subjective prediction, objective prediction, and simple statistical methods. (Prusty, 2017)

3. RESEARCH OBJECTIVES

- To understand the various uses of OR in the field of sports.
- To study different OR techniques used in the sports industry.
- To find commonalities between OR techniques used in different sports fields.
- To elaborate on the advantages of using OR to have improved overall management and decision making.

4. RESEARCH METHODOLOGY

This research paper uses extensive Analysis to study Operations Research in sports. Through this Analysis this paper combines and reviews multiple scientific studies on sports such as football, basketball and cricket and how they incorporate similar Operation Research techniques and strategies. Through this form of analysis, the paper also incorporates the measures that are expected to have some degree of error or limitation. The research includes an overview of the industry as well as the application Operations Research in specific fields of the sports industry. All of the data present in this research paper is taken from pre-existing secondary data, in the form of research papers by scholars, students, and professionals in the field of Operations Research, as well as interpretations of these papers.

5. ANALYSIS

5.1 Operations Research in Basketball

Basketball could be considered as a symbolic field where these differences in decision-making can be met. With the help of statistical analysis, the selection and recruitment process can be made simpler in order to support the management. There are many variables to be considered such as the players, opponents, home advantage vs away disadvantage. The strengths and weaknesses of the team players as compared to the opponent's strengths and weaknesses. the analysis of all this data will help select the best team in order to the best results. (Nikolaidis, 2015)

5.2 Operations Research in Cricket

Analytics in Cricket is not a new idea. A lot of Operations Research societies, especially from the Commonwealth nations, would be pleasingly surprised to learn that OR has been an essential part of cricket (in particular, the limited-overs versions) for the last 16-odd years. The reason behind this is official induction of the Duckworth-Lewis rules for weather-interrupted matches into the rulebook. Mr. Duckworth and Mr. Lewis are OR/Math guys. According to cricinfo, Mr. Lewis is/was the chairman of the western branch of the Operational Research society in the U.K. Cricket is more than a century old, and is the second-most followed sport in the world (thanks to more than a billion and a half cricket-mad fans from the Indian subcontinent, including this author). India is the No.1 test cricket team in the world today (after 77 years of hapless performance), and cricket is now big business that is growing in size, with all the professional leagues like the IPL coming up. Among all sport, cricket reflects life the most, and its rules suitably mirror this. It's best been described as having a disguised gentlemanly exterior which hides a series of brutal one-on-one gladiatorial contests of blood, guts, and stamina, which is then enfolded in a chess-game of brains and strategy, and tied up with strings of psychological tactics of mental fragmentation. (Shiva, 2009)

5.3 Application of Operations Research in Cricket

Duckworth-Lewis is a method of resetting targets in cricket matches that have been interrupted and could not continue their full duration or finish the match. This method is originally designed for one day cricket matched but after the world cup in 1999 this method has expanded to other formats such as twenty-twenty, the Duckworth-Lewis method has been adopted by all the international cricket boards and associations. Cricket, originated in England, is the most popular game in the country with huge fan following of the enthusiasts. This has paved a way for growth of an enormous cricket industry in India, there has been substantial development and improvement of cricket rules and regulations over time. This development is a result of statistical, mathematical and operations

research used to improve the sport, thus Duckworth-Lewis is considered as one of the most significant contributions to the sport from the analytical and research perspective. The Duckworth-Lewis method, initially designed for one-day matches, when applied in twenty-twenty matches was recognized as unfair and advantageous to the first batting team, this approach was reviewed and developed, considering reducing the target 0.5% per over lost. This too seemed to favor the team batting first and thus needed further review and evaluation. The data used to make the resource table is consist of all international twenty-twenty matches to date involving nations from the International Cricket Council (ICC). The resource table for twenty-twenty matches is obtained using a nonparametric approach based on Gibbs sampling. The resource table is derived after assessing the resources available for the team whose inning has been disrupted, the resources available along with the overs left are used to derive resource table. To facilitate the comparison between the tables a heat map is used. The findings of the research paper shows us that the darker shades of the heat map reveals that the greatest disagreement between the two tables in the top-right hand corner and bottom left hand corner of the table, these are the regions where little or no data are available and are not regarded as too important regions also it was fascinating to know that the nonparametric approach provides more resources in these regions than the Duckworth-Lewis approach. It is important to know that the nonparametric resource table cannot be endorsed as a replacement for Duckworth-Lewis resource table as the resource table is based few amounts of matches (85) which are too small as a sample to provide bold and considerable information.

The Indian premier league (IPL) is a professional T20 cricket league in India contested during March or April and May every year by eight teams representing eight different cities of India. The league was founded by the Board of Control for Cricket in India (BCCI) in 2008.[3] This reduced format is very popular among playing nations, players and the public. Since the IPL is a high budget event where each team has invested up to \$5 million on all the auctioned players sufficient care is taken by the clubs to buy the right kind of players. All the teams would be wanting to win the cash price, win the league and ranked high as well. Among the techniques of operations research used in comparing the efficiencies of teams, Data Envelopment Analysis (DEA) has been used extensively. DEA (Charnes et al., 1978, Banker et al., 1984) can be viewed as a linear programming-based technique. DEA is used to empirically measure productive efficiency of decision-making units (DMUs) and is also used in benchmarking the performance. Peterson et al. (2008) observed that winning teams pick wickets at the beginning and end overs while they contained the opposition during the middle overs.

A particular team in IPL can acquire players through the player auction, by trading players through the trading window and getting replacements for players that are unavailable. The players' performance is analyzed and value is put to it. The valuation of players is a crucial part that has to be considered. There are several ways of analyzing the performance, performance-based index, hedonic pricing, ordinary least square regression technique, and AHP-ANN Model. In the performance-based index, the distribution examples of the present estimations of cricketers are recognized and cricketers are classified in light of the level of present qualities. Hedonic Pricing Analysis is based on the theory that a good/service can be treated as an accumulation of attributes that differentiates it from other goods/services. The hedonic price equation, in this context, is a locus of equilibrium final bid prices and player attributes, where buyers (team owners) and sellers (cricket players) participate in an auction (Rastogi and Deodhar, 2009). Under this model the price and evaluation of a player are based on internal and external factors. The least-square regression technique uses dependent variables that cover a variety of performance factors such as batting and bowling average in different forms of cricket like T20 and ODI, experience in different forms of cricket and different characteristics of the players. The AHP-ANN Model in IPL is used to estimate the price of a player which depends upon various criteria and then the AHP process is used to measure the weights of the criteria which are responsible for the player price estimation and then ANN is used to find the cost of each player with weights known by AHP.

5.4 Operations Research in Football

“Professional Game Match Officials Limited (PGMOL) denies Halsey's claims that officials have been told to lie”.

Stevens, 2016.

PGMOL is a body of select individuals that appoint referees in football matches based on certain parameters such as current form, the importance of the match, teams which they individually support, experience, etc. This research paper talks about how operations research is used in football In various ways such as appointing referees, distributing teams, and others explained further in the paper. It also takes into consideration the FIFA world-cup in its study. This year FIFA world cup costed an estimate of 11.8 billion making it the most expensive world cup to date. (Sheetz, 2018)

For numerous years individuals have looked into approaches to streamline strategic and quantitative techniques for various games. Notable techniques for the same are Freeze (1974) who used simulations to locate the best batting order for a baseball group, Boon and Sierksma (2003), who designed a decision support system to help football coaches and administrators survey contributions of specific players to their groups, thus helping in group determination as well as in scouting and buying new players, Scarf and Grehan, (2005) decided the ideal course to pick while cycling.

Gambling has been a major element of sports, where high amounts of money are involved and it is highly likely that a large number of OR techniques are used which are viewed as “highly classified” in the public eye.

Football is slowly but steadily becoming one of the most popular sports across the globe. The game has been catering to the needs of sports fanatics with a huge budget. For the same reason, there are quite a few studies which are based on football.

5.5 Scheduling Process

The football scheduling process is a tedious task involving at least 100 permutations and combinations. The scheduling programs solution is developed using several techniques such as integer programming, constraint programming, local search heuristic, decomposition approaches and combinations thereof. The process generally involves mathematical derivation of objectives and requirements put forth by the stakeholders to obtain a solution that is presented to the stakeholders for their opinions which are then taken into consideration to develop other optimal schedules. (Fry)

Previous research shows while developing a schedule for the Brazilian Football Tournament, an integer program was devised to obtain schedules. The major aspect that was focused on to devise the schedules was the maximization of game attendances and TV audiences. First, several feasible patterns of home and away games were developed. Then, the home-away patterns were assigned to the teams then, a reduced integer program was solved to schedule the matches accordingly. (Fry)

Very similar methods were used in devising Chile's Second Division League and Canadian Football League's schedules as well. Previously, schedules were being made by coupling each game date with two numbers that were assigned to respective teams in random order. However, in 2005, the ANFP asked a few operation types of research to draft new techniques to the first division schedule of Canadian football league.

As a result, an integer programming model was developed that took into consideration the constraints that were put forth by the ANFP. After the major success of the first division, the second division followed suit by developing a new ILP model based on basic, break and geographical constraints. The major focus on developing both these schedules was the improvement of public sentiment, as well as the economic viability of Chile. The research concluded that the OR techniques had a significant qualitative as well as quantitative impact.

The use of OR techniques to schedule matches is widely accepted and praised because it ensures transparency, and most importantly it is relatively easier to draft alternative schedules using OR techniques as compared to other ones. They also take into consideration the requirements of the stakeholders, which is a major factor in coming up with a solution that satisfies all given conditions/constraints.

5.6 Referee Assignment Problem

This is an important element in the football league. Assigning referees in an inefficient manner can lead to the disruption in the flow of the game as well as cause losses to the given stakeholders of the game. Each game requires four referees; 1 center (chief authority of the game), 2 assistants (linemen) and a 4th referee (keeps a record of red and yellow cards and is a substitute for the center referee). Rifts and disagreements between Clubs (teams) and the referees are a common sight. This gives rise to unnecessary tension between them and hence fair referee assignment is extremely important. (Mesut Yavuz, 2008)

This research paper talks about obtaining the initial feasible solution (IBFS) along with a search procedure to improve the solution obtained. The research paper suggests that the basis of the assignment should be two major criteria:- Fairness and Performance. The referee assignment problem is periodic in nature. It states that to avoid short periods, it is necessary to have a number of referees than the total games in the season. (Mesut Yavuz)

5.7 Effectiveness of Football Teams

The purpose of football teams to compete in a tournament is to win while the ultimate goal is to survive. A club can only perform if well if it makes profits while surviving in the competitive nature of the game. Hence, the research takes into consideration Champions League and performs an analysis on the teams on the basis of their efficiency. The method used is the Data Envelopment Analysis (DEA) to measure efficiency. (García-Cebrián)

The study states two finalists are efficient in each season. However, there are also a few teams that get eliminated early in the season but have utilized their resources with utmost efficiency. It also states that the winning team is not always the most efficient team in the season. The three main conclusions that were put forth by the study were:

- Efficient use of resources is extremely necessary to attain good satisfactory results
- Efficiency can be used to more accurately define the results of various teams on the basis of resources available to them
- The inefficiencies recognized during the study can be attributed to the wastage of resources and not the usage of different tactics. (García-Cebrián)

5.8 FIFA

In this research paper, it is decided to study the kingpin of soccer that is FIFA, for finding out the extent of quality of operations research used in the field. Studies on FIFA are huge and it is mentioned that the subject itself outranks the studies on major cricket association board BCCI (Board of Cricket Control in India) by margins. FIFA uses OR techniques to make key decisions about the game such as design of the football, goal posts, as well as goal lines and uniforms of teams, weather forecasting to decide the venues, and numerous other decisions as seen and published by various articles and news agencies such as economic times, etc. The economic times had published a 7 items list article mentioning the OR techniques used for bettering the various paraphernalia used in FIFA 2018. Talking about the sponsors of FIFA, there have been many recognized sports brands such as Puma, Nike, Adidas, etc. respectively that use OR techniques to boost their sales. FIFA uses both lower models such as linear and nonlinear programming tools to determine the grounds and audience arrangements as well as higher models stochastic programming to determine various social, economic a geographical condition that may affect the federation.

5.9 Application of Operations Research in Basketball

Visual function, performance, and processing of basketball players in comparison to individuals without any sporting background:

Athletes tend to have a much better visual-motor performance when compared to the sedentary individuals but there are several basic visual-function and perceptual parameters that are yet to be explored till date hence, there is a need to identify whether differences exist in visual function, performances, and processing between basketball players and individuals without any sporting background. Athletes, in general, need to gather an immense amount of information, mainly visual, swiftly from the environment in order to act appropriately and execute the relevant motor tasks. Several studies in the past have questioned whether the visual skills amongst the athletes are innate or have improved over time with systematic relevant sports practice.

Basic visual functions like those dependent on good optical quality, oculomotor coordination, binocular and accommodative function or stereopsis are all crucial to success in all kinds of ball games, especially in basketball. To add to it, a player's performance also depends on the cognitive capabilities and visual-motor reaction times.

It has not been clarified whether the athletes' superiority is due to basic visual functions or due to perceptual and cognitive skills. Therefore, various parameters have been used by investigators to ascertain this aspect such as accommodative response, near point of convergence, near and far fusional vergences, visual-discrimination capacity, visual reaction time and eye-hand coordination.

5.10 Visual information processing

The Wayne Saccadic apparatus is used for evaluating the visual-reaction time. It is an apparatus consisting of a 29-inch square panel containing 33 red lights switches. A computer chip generates light to which an individual responds by pushing the illuminated switch to extinguish the light. A great variety of display patterns, speed and situations can be programmed. The players that participated in the test were instructed to press the start button, holding down the button until a signal is heard, releasing the button and pressing the illuminated light button on the saccadic fixator.

To test the eye-hand coordination, a test developed by Dr. Jack Gardner and Wayne Saccadic Fixator is used, which jointly takes into account the pro action and reaction times undertaken by the participants. In this, the light starts moving at a preset speed and for each correct response, the speed increases. At the end of the present time, the display shows the number of correct responses, average speed and final speed in terms of light/minute. The score is the product of number of lights scored and the final speed of the presentation of lights.

In basketball, near-far visual changes are continuous for ball interceptions, controlling, passing, throwing the ball as well as in the cases of analyzing the positioning of the teammates and the opponents constantly promoting a constant implication of the vergence and accommodative system. It is notably found that the basketball players present a closer near the point of convergence and larger far positive fusional vergences in comparison with the sedentary/inactive group.

The ball and the players, in the game, move mainly at medium term distances, which does not require great accommodative effort. Therefore, accommodation enhancements requiring high accommodative stimulation in visual training are unlikely to be achieved only with regular basketball practices.

The glare phenomenon has been given great importance in basketball as the players are constantly exposed to glare due to illumination conditions in basketball courts. Such differences found between basketball players and sport inactive individuals could be explained from the perspective that abilities involved during the game are inherently developed while playing the sport as it occurs in the case of international basketball players.

Various results confirm that basketball players show better eye-hand coordination compared to individuals without any basketball background. As far as visual-reaction time is considered, players from different disciplines have varying and faster visual-reaction time compared with novices/non-athletes. Various studies in the past have found and stated that the differences between an athlete and a sedentary individual arise from visual-information processing and interpretation rather than from basic visual skills. A recent study had also indicated that visual tracking speed is also related to a greater number of assists and steals and lower turnovers in NBA players.

Hence, it is evident that there are vast differences between basketball players and inactive in sports individuals with respect to some skills like visual function, performance, and processing. This suggests that systematic basketball practice might be responsible for the development of certain visual abilities.

6. FINDINGS

The main commonality between all three of the analyzed sports (cricket, football, and basketball) is the use of scheduling models. Hence, we will further analyze problems of 'sports scheduling'. OR techniques have been extensively used for scheduling. Due to the geographic challenges and restrictions making a feasible schedule model is of utmost importance. The models also help the sport from being scheduled in their 'home cities' in case there is another major event happening during the same time. The constraints that are commonly used in all these sports are geography, place, type of game, number of players, pattern of the game and type of field required for the game.

A frequently used model in scheduling is the 'Round-Robin' also known as the 'League stages' model. Another model used is the referee assignment problem, however, due to its extensive process it is very rarely used. The third type of model is the model that

measures the effectiveness of sports teams. By using talent and capabilities as input and points won and revenue generated as output, this model measures the efficiency of the teams. This model is generally used in larger league or international level games.

Fun fact: one can use this model to select and support a favourite team based on their performance efficiency.

Another commonly used Operations Research study in the sports industry is 'Network Theory Analysis'. This is done to measure the performance of teams too. The different measures used to derive results via this analysis are the popularity of a player, the effects of substituting players from a game and the relative importance of players. The Accuracy of passes in football and basketball can be derived through a similar model. This study will usually be beneficial for coaches to decide substitutions. Another commonality is the DEA (Data Envelopment Analysis). It uses benchmarking the performance and then measures the efficiency of the players. It is commonly used in football and cricket.

7. CONCLUSIONS

Operations research in sports is a vast field that has been researched over the past few decades in areas such as tactics and strategies, scheduling and forecasting [4]. Anyway, this isn't the end as there are different fields of focus study like the unorganized sports zone. There will be sophisticated OR programming software that will make further progress in the fixtures and officials (and conceivably different things, for example, training facilities) for experts as well as at beginner level also. There is presently an enormous measure of information accessible for a developing number of sports, catching pretty much every feature of a sports experience on a computer in a form susceptible to quantitative analysis. This empowers modern OR models to be of practical value to decision-makers in a sport. This trend will proceed, and it likely could be that OR will turn into an acknowledged device in helping players, mentors, coaches, owners, and others to plan and play their games.

8. LIMITATIONS

- Since this above paper was based on secondary research, a lot of information had to be filtered that was not necessary or a part of the title of this paper.
- Secondary data that may have been collected well in the past may now be out-of-date information that may offer little value.
- The information and data may not be accurate. The source of the data must always be cross-checked.
- Official statistics may reflect the biases of those in power – limiting what we could have found out.

9. REFERENCES

- [1] Leung, Carson & Joseph, Kyle. (2014). Sports Data Mining: Predicting Results for the College Football Games. *Procedia Computer Science*. 35. 10.1016/j.procs.2014.08.153.
- [2] R Fildes, K Nikolopoulos (2008) "Forecasting and Operation Research Review" *Journal of the Operational Research Society*, Volume 59, Issue 9.
- [3] Chauhan, Navyaashali, et al. "A Study of the Application of Operations Research in the Valuation of Players in IPL." www.ijariit.com, *International Journal of Advance Research, Ideas and Innovations in Technology*, 2018.
- [4] Prusty, M. (n.d.). A Study on the application of Operation Research in Sports and Sports Management. Retrieved from Medium: <https://medium.com/@imprusty/a-study-on-the-application-of-operation-research-in-sports-and-sports-management-90f3613df174>
- [5] Babu RJ, Lillakas L, Irving EL. Dynamics of saccadic adaptation: differences between athletes and nonathletes. *Optom Vis Sci* 2005;82: 1060–5.
- [6] Del Percio C, Brancucci A, Vecchio F, Marzano N, Pirritano M, Meccariello E, et al. Visual event-related potentials in elite and amateur athletes. *Brain Res Bull* 2007; 74:104–12.
- [7] Barrett BT. A critical evaluation of the evidence supporting the practice of behavioral vision therapy. *Ophthalmic Physiol Opt* 2009; 29:4–25.
- [8] Ludeke A, Ferreira JT. The difference in visual skills between professional versus non-professional rugby players. *South African Optom* 2003; 62:150–8.
- [9] Schwab S, Memmert D. The impact of a sports vision training program in youth field hockey players. *J Sports Sci Med* 2012; 11:624–31.
- [10] Quevedo-Junyent L, Aznar-Casanova JA, Merindano-Encina D, Cardona G, Solé-Fortó J. Comparison of dynamic visual acuity between water polo players and sedentary students. *Res Q Exerc Sport* 2011; 82:37–41.
- [11] Laby DM, Kirschen DG, Pantall P. The visual function of Olympic-level athletes-an initial report. *Eye Contact Lens* 2011; 37:116–22.
- [12] Sillero M, Refoyo I, Lorenzo A, Sampedro J. Perceptual visual skills in young highly skilled basketball players. *Percept Mot Skills* 2007; 104:547–61.
- [13] Evolutionary Multi-Objective Optimization and Decision-Making Approaches to Cricket Team Selection. Kanpur Genetic Algorithms Laboratory (KanGAL), <http://www.iitk.ac.in/kangal>.
- [14] Hazarika, Partha Jyoti. "A Study on Performance of Cricket Players Using Factor Analysis Approach." <https://www.ijarcs.info/Index.php/Ijarcs/Article/ViewFile/3072/3055>, *International Journal of Advanced Research in Computer Science*, Mar. 2017.
- [15] Sangwan, Hemant, and Deepak Kumar. "Duckworth-Lewis Rule Based On Operation Research." http://ijirt.org/Master/Publishedpaper/IJIRT102103_PAPER.Pdf, *INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN TECHNOLOGY*, 2015.
- [16] Krishnamurthy, Nagarajan, and N Ravichandran. "DEA Model in Relative Ranking of Private Cricket Team: Some Instances from the Indian Premiere League." *Advanced Workshop And Tutorials On Operations Research (AWTOR-2012)*, ALLIED PUBLISHERS PVT. LTD., 2012, pp. 102–116.

- [17] FootballandOperationsResearch.<http://www.orcomplete.com/research/sertalpbilal/football-and-operations-research>)
- [18] Stevens,S.(2016,September4).MarkHalsey:Formerreferee'sclaimsthatofficialshavebeentoldtolieaftermatcheshave been denied. Retrieved from Independent: <https://www.independent.co.uk/sport/football/premier-league/mark-halsey-referee-pgmol-fa-claims-accusations-lie-sergio-aguero-manchester-city-united-a7224916.html>
- [19] Yavuz,Mesut&Inan,Umut&Fıgıllı,Alpaslan.(2008).Fairrefereeassignmentsforprofessionalfootballleagues.Computers & OR. 35. 2937-2951. 10.1016/j.cor.2007.01.004.
- [20] Sheetz, M. (2018, 06 14). Here's who is getting rich off the World Cup. Retrieved from <https://www.cnn.com/2018/06/14/the-business-of-the-world-cup--who-makes-money-and-how-much.html>
- [21] Urrutia, C. C. (n.d.). OR On the Ball: Applications in sports scheduling and management. Retrieved from <https://www.informs.org/ORMS-Today/Archived-Issues/2004/orms-6-04/OR-On-the-Ball-Applications-in-sports-scheduling-and-management>
- [22] Cay, S. B. (2012, July 4). Football and Operations Research. Retrieved from OR Complete: <http://www.orcomplete.com/research/sertalpbilal/football-and-operations-research>
- [23] Willoughby, K. J. (2012). A Decision Support System for Scheduling the Canadian Football League. Retrieved from www.jstor.org/stable/23254869
- [24] Mesut Yavuz, U. H. (2008). Fair referee assignments for professional football leagues. Retrieved from https://www.researchgate.net/publication/220473082_Fair_referee_assignments_for_professional_football_leagues
- [25] Keith Goldner (2012) A Markov Model of Football: Using Stochastic Processes to Model a Football Drive. <https://www.degruyter.com/view/j/jqas.2012.8.issue-1/1559-0410.1400/1559-0410.1400.xml>
- [26] "European Journal of Operational Research." European Journal of Operational Research | Sport and Computers | ScienceDirect.com, <https://www.sciencedirect.com/journal/european-journal-of-operational-research/vol/148/issue/2>.
- [27] "What Is Operations Research and Why Is It Important?" WhatIs.com, <https://whatis.techtarget.com/definition/operations-research-OR>.
- [28] "Analytics in Sport - Cricket and Operations Research - 1." Analytics in Sport - Cricket and Operations Research - 1, 11 Dec. 2009,
- [29] Prusty, Manoranjan. "A Study on the Application of Operation Research in Sports and Sports Management." Medium, Medium, 24 Oct. 2017, <https://medium.com/@imprusty/a-study-on-the-application-of-operation-research-in-sports-and-sports-management-90f3613df174>.