

Application of Operations Research in Gaming and Sports

C006-Akshat Maharwal

C007-Akshit Sanghavi

C008- Anoushka Jaipuria

C009- Arpan Kapoor

C010- Bhagya Bhardwaj

Student, NMIMS, Anil Surendra Modi School of Commerce, Mumbai Campus

Abstract

This study aims to examine the application of operations research via quantitative and decision-making techniques in the field of sports and gaming. It examined various research papers in sports such as cricket, football, F1 racing and casinos and arrived at its findings. It finds there are certain common applications and elements in field sports such as cricket and football while applications are very different in gaming and dF1 racing. The commonality is that Operations Research has been used to optimise a key success factor in each of these sports. For example, the process of changing tyres in F1 racing and the placement of slot machines in a casino. In field sports, operations research techniques are used in terms of scheduling matches which are inter-city and aim to minimise travel time. This secondary research concludes that Operations Research can certainly improve performance in a sport and the key output matrix in the organisation of sports. However, it also concludes that the extent of improvement critically depends upon the identification of the right matrix in the first place and the application of right tool and techniques.

Keywords: Scheduling (cricket and football), Optimisation, placement of slot machines, Tyre changing techniques, Strategies of Operations Research in football and cricket

Introduction

The Olympics and Commonwealth Games are the largest sports tournaments in the world. They have the capacity to shape and project the image of the respective host country to the world. This may in-turn make the host country attractive for political and economic inflows. (Estilla Lins). There is so much pressure and weightage on these tournaments which require prolonged planning, strategizing, organisation and implementation. This is where Operations Research comes in. It aids decision making, higher productivity, increases efficiency and coordination. In sports, Operations Research is mainly used for scheduling (inter-team and inter-city), forecasting and generating strategies to achieve optimisation in the sport. For instance, the Commonwealth Games held in Delhi in 2010 faced many issues in terms of its organisation and planning. The sports village and infrastructure was not ready which led to limited staying quarters and washrooms. The travel time to and from the venue was also very high which led to player exhaustion (Bose, 2010). Thus, Operations Research could have been used in a more effective manner so as to decrease travel time, exhaustion and cost.

Operation Research is the use of analytical models and techniques to achieve optimisation and improve the efficiency in decision making (Trick, 2011). In this research paper we are going to explore the application of Operation Research in the Sports and Gaming industry. Sports forms a huge part of all our lives, young or old, all around the world. Most of us love watching various kinds of sports and at least watch some kind of sports every single day. Various competitions involving various teams and locations happen all year round. For example, after the IPL this year the players had to rush for the World Cup. Each of these competitions require vigorous planning and strategizing, both for the organisation and the actual sport. For example, the scheduling of inter-city, inter-team matches which involves players from all over the world will use Operation Research techniques to reduce travel time of players, reduce exhaustion, or to work on a budget/timetable etc. In F1 and car racing Operation Research is used to formulate strategies wherein they can minimise the time taken to change tyres and thus achieve optimisation.

When it comes to the gaming world, we are going to explore the use of Operations Research in casinos and thus gambling. At most casinos the bulk of revenue is obtained from slot machines. Thus, it is necessary to plan and strategize the mix of the slot machines to maximise revenue. To configure the optimal mix of slot machines operations research is used (mainly Linear Programming) (Kasra Christopher Ghaharian, 2011).

Overview of the Sports Industry

Sports according to Wikipedia is described as all of the following:

- Entertainment – Any sport that includes spectators, either free or paid admission, with no pre-scripted plot of the final outcome. The athletics might also get entertained by complete sports objective.
- Exercise – some sports are physical exercise while others are mental exercise.

Sports is played all over the planet, whether as hobby, career or as a part of fitness regimens. Over the years various sports has gained tremendous popularity, with more than half of the world's population considering themselves as football fans. Cricket taking a close 3rd place followed by and Hockey and Tennis. Most sports are governed by their respective international bodies. Countries from all around the world compete against each other in world cups and tournaments.

The 2018 FIFA world cup costed around USD 11.8 billion, making it the most expensive world cup till date. There are more than 3.5 billion followers of football. Lionel Messi earned an estimated USD 120 million in 2018, making him one of the highest paid athletes. Clearly, an upsurge in the happening of sporting events and competitions has led to advancement of the sports industry (all business activities related to sports) over the last centuries.

Another major transformation is the use of quantitative methods and research in sports. Decisions and strategies are no longer made by intuition or gut feelings, instead there are mathematical models that do complex problem solving in seconds. From calculating the speed of the ball to scores given to players by judges, mathematics is omnipresent in the world sports

The advancement in technology has made it possible to improve performance. With research, feats that once seemed impossible have now become mere standards.

Research Objectives

1. To identify key studies that have examined the application of operations research to specific sports/sporting activities
2. To study the application of Operations Research in F1 racing with focus on minimising time required to change tyres
3. To analyse how Operations Research is used in cricket (scheduling inter-city matches plus strategies)
4. To study the contribution of Operations Research in the optimal placement of slot machines in casinos with the motive to earn maximum revenue
5. To understand and study the use of Operations Research in football scheduling and strategizing

Research Methodology

We have analysed various research papers pertaining to Operations Research, Application of Operations Research in the Sports Industry and specific papers where in we have analysed the application of operations research in Cricket, Football, F1 racing and Casinos. There were various key factors which influenced and filtered our research, for example, the scheduling of matches via Operations Research, various techniques to identify batting order and how to minimise player exhaustion and travel time etc. We have also aimed at drawing a trend wherein Operations Research has enhanced the outcomes in each of the four selected sports. We also looked at key points of differentiation in the application of operations research in the four chosen sports.

Literature Review

Spectator sports are pervasive in society. The worldwide TV viewing audience of certain events in recent Olympic games and the World Cup Soccer Tournament is estimated at 2-3 billion people, about half of the world population. Track and field athletes have traditionally pursued performance optimization in an artistic rather than a scientific manner. But many of the tactical decisions made by athletes in these events, most of which are currently made by intuition, can be analysed quantitatively to provide optimal results for the participants. (Gerchak, 1994)

Football is one of the most followed sports in the world. In the late 19th century, football clubs existed with little to no profits but now clubs like Real Madrid and Manchester United have over \$688 million per annum revenue with both clubs worth over \$3.5 billion, as of 2017.

Scheduling of matches in football has been one of the most sought after Operations Research problems for years. In the English Football there are three bodies that are the Football Association, the Premier League and Football League. Each of these is being divided into divisions. The top division being the Premier League. To produce the required double round robin tournament for each division, I could use algorithms drawn from the literature, with one of the most common being the polygon construction method. However, this method is unlikely to produce a fixture list that is acceptable to all interested parties (which include the football authorities, the football clubs, the supporters, the police, etc) as the algorithm does not cater for all the real-world requirements that make up an acceptable set of fixtures. (Kendall, 2008)

Also, there comes a transportation problem with all the matches being played in different parts of the world. Every club in the premier league plays another club two times, once in their home stadium and once in the other team's stadium which counts as an away game for the first team. With additions like the Championship games or the UEFA Champions League or Europa League games (for top six teams only). These games make transportation cost optimization difficult.

Cricket which is England's national summer sport now played throughout the world, particularly in Australia, India, Pakistan, the West Indies, and the British Isles. Initially played only in one format in which a game was played for 5 days and each team batted and fielded 2 times each which is called as a test match. Since the late 20th Century two new formats have developed which are One Day and Twenty-Twenty in which one team bats and fields one time for 50 overs and 20 overs respectively.

One of the most important contributions of Operations Research to Cricket was the Duckworth and Lewis Method to calculate the result of the One Day Matches which have been paused due to weather conditions as cricket cannot be played in rain or stormy weather. The Duckworth/ Lewis (D/L) method of target resetting in interrupted one day cricket was

first used in one-day internationals (ODIs) in Zimbabwe on 1 January 1997 and in national one-day competitions during the 1997 season of the England and Wales Cricket Board (ECB). Following slight modifications to the method's implementation in 1998, it has gradually spread to be used in all major one-day cricket-playing countries both for their national competitions and in internationals. (FC Duckworth, 2004)

The introduction of the D/L method in 1997/1998 caused considerable, frequently unfavourable, comment among players and journalists.^{4,5} Using mathematics to assist in administering the game was novel and difficult for some people and an anathema to others. Following its successful use since that time, the method has spread to be used in all major cricket-playing countries. It has been used well over 400 times in national and international matches and probably many other times in matches below national level. Although many journalists still enjoy making disparaging comments about the method, there is general acceptance of its superiority over all other methods that have been tried. (FC Duckworth, 2004)

Formula 1 racing originated during the 1920-30s in Europe from other similar racing competitions. In 1946, the FIA standardized racing rules and this formed the basis of Formula One racing. The inaugural Formula One World Drivers' championship was then held in 1950, the first world championship series. Apart from the world championship series, many other non-championship F1 races were also held, but as the costs of conducting these contests got higher, such races were discontinued after 1983. Each F1 team can have maximum of four drivers per season. There is support staff with every F1 team that plays a vital role in the team's success. (tutorialspoints.com)

Operations Research in Formula 1 is used in many things. First is the optimality of the tyre usage. There are 3 types of tyres are soft, medium and hard type. The use of optimal tyres is necessary for each type of track for maximum speeds and durability. Also average time is also linear programming for the drivers and to calculate optimum time for each part of the course. (J Bekker, 2009)

Gambling has been a fixture throughout history, with members of every era and age enjoying a little bit of a bet. The earliest gambling was recorded by the Chinese in about 2300 B.C, where tiles were found that corresponded to people's enjoyment of gambling with one another, whilst ancient Egyptian dice have also been found, dating back to around 1500 B.C. Defining the exact time period that gambling was invented is almost impossible, but we're able to put our finger on when the first official casino came into fruition. The first casinos or gambling houses appeared in Italy in the 17th century; The Ridotto was established in Venice in 1638 to provide a controlled gambling environment, and casinos started to appear throughout continental Europe in the 19th century. Casinos today are huge industry grossing over \$3.28 billion in the year 2018. (medium.com, 888casino.com)

Operations Research in Casinos is used as to optimize the Casino Slot Floor which can be calculated by using Linear Programming. This method helps in usage of Slot Machines on the Casino Floor for maximum revenue and to reduce the chances of gamblers hitting Jackpot. (KC Ghaharian, 2009)

Findings

Formula 1:

Formula One is one of the world's most high-paced sports, with race cars rushing at extreme speeds. Fractions of a second can cost a win. In F1 it all comes down to time, more specifically, the time saved.

For the teams, a race strategy is as important as aerodynamics, mechanics, engine power and the driver. Strategies are no longer made by gut feelings or intuitions. Race strategy decisions are based on data analysed through millions of scenarios weeks in advance, and during the race itself. (SPURGEON, 2008)

Pit stops are pivotal in Formula One. It is a crucial moment where teams can save or lose a significant amount of time. By stopping and making adjustments to the car during a pit stop, F1 drivers can actually go quicker between pit stop, ultimately overcoming the time taken for them to make stops in the first place. Thus it is very important to strategize pit stops. (F1 strategy and pit stops, n.d.)

A constant analysis of relative track positions, fuel consumption, tyre wear and weather conditions, along with a host of other factors is done by the mathematic models.

For instance, in a race circuit where overtaking is very difficult, the importance of pit stop and race tyre strategies is enlarged.

There are 3 types of tyres

1. Hard – High Durability but comparatively slower speed
2. Medium – Balance between durability and speed
3. Soft – High Speed but low durability

Type of Tyre (Status of tyre)	Time compared to Optimal time (per lap)
Soft (new)	0s
Soft (Worn)	-1s
Medium (new)	-0.4s
Medium (old)	-1.4s
Hard (new)	-0.7s
Hard (old)	-1.7s
Pitstop	-25s

The optimal race time would be running all laps on new soft tyres. This is not possible however, as tyres wear down after periods of use. Once they are in this worn state they will lose approximately 1 second a lap. Consequently both tyres and their states, as well as pit stops can be compared with the optimal race time (Whittle, 2012)

To form a pit stop tyre strategy, a simulation model is developed.

The average time to overtake is continuously determined. A position change from an empirical distribution function is drawn to determine the number of positions lost or gained by each driver. The next step involves the overtaking model. It computes the difference in cumulative lap time between each consecutive pair of drivers on the circuit. The overtaking model determines whether any driver was able to overtake another driver. (Sulsters, 2018)

Now if Driver A and Driver B are fighting for the 1st position and driver A is leading, to close the gap or even overtake A, Driver B might consider changing tyres. Now the loss in time due to pit stop is traded off with the gain in time due to new tyres. If the model suggests a positive result, then a pit stop is made and new tyres are put on. The model also suggests particular laps for the pit stops.

This is an example of the use of game theory – the part of mathematics involved in strategic decision making. It is the task of trading off between different factors, something computers can do much better than humans. For instance, it is good to find the optimum time to come in and change tyres, but if the driver re-joins the track trapped behind multiple slower cars then he will have to waste time finding space to overtake them. On the contrary waiting another lap, even though slowing the driver down a bit due to further tyre wear, could bring him out of the pit lane free to motor on his new tyres, more than making up for the delay of the extra lap. (F1 strategy and pit stops, n.d.)

Cricket:

Cricket is over a century old and is the second most followed sport in the world. One of the greatest Operation Research techniques ever developed i.e. Duckworth-Lewis, was related to the revised calculations of scores of an interrupted cricket match due to bad weather conditions. Before this method, the target scores for interrupted matches was decided via run-rates enabled by the remaining overs and not the wickets. This was not optimal and hence the Duckworth-Lewis method came into existence. When the match needs to be shortened, there has to be a revised target set for the second team as they are the ones who will be unable to play the entire remaining overs. This method was fully accepted by all boards across all competitions and was drafted keeping in mind one day cricket. However, now even Twenty20 cricket matches started implementing this method after some alterations of rules as there is a shift from 50 to 20 overs (Hemant Sangwan, 2015). The main essence of this method is resources namely, wickets and overs left. At any point, the number of runs will depend on either or both of these resources. The score that is fair to both teams after taking all combinations into consideration is chosen as optimal.

Operations Research is also used in cricket in terms of the batting order. Many times we hear people say, “He is a good opener” or “He is the perfect number 2” implying that he makes the most runs when he comes to play at a particular number. The number of runs in cricket simply depends on the interaction between the bowler and the batsman. The Markov Chain is used to determine the batting order which states that the past and future scenario does not matter

and the only thing that does matter is the current state, for e.g. if a bowler suddenly turns and goes it creates a new scene. A probability matrix is made based on available current statistics and batting order thus decided. Without this, the order would usually be decided via gut or the talent and experience of the player. Thus, the use of operations research improves the efficiency and gives a backed answer with proper reasonings as to why and how. (Ursin, 2014)

A large part of Operations Research in cricket is the scheduling. The scheduling of matches can range from easy to hard depending on the scale of the tournament. If a tournament has more than fifteen teams and is an inter-city tournament such problems become difficult. The scheduling of matches can achieve optimality depending on what is given most importance, for example, to minimise the travel time for players (travelling tournament problem), to minimise the player exhaustion or can be to increase tickets revenue. Over the weekend they may schedule a match where they know people will go out and buy especially cause they would want to step out on the weekend example, Mumbai. Usually, in scheduling matches there are a few constraints. Some are game constraints, example, IPL they will ensure a big match (Mumbai vs Chennai) is scheduled for a weekend so that everyone wants to come and watch. Some venue may not be available on a particular date and there may be rules like there can be only a certain amount of home games and away games like IPL. Another technique they use to achieve optimality in terms of audience satisfaction is Factorisation and Minimum breaks. This means that after away game they come back home instead of travelling directly to the next venue as the audience at home does not have to wait a long period to see their regional team play and thus they also ensure regular earning from home games and thus maximisation of revenue. (Rasmussen, 2007).

In Cricket, every situation/ problem that occurs can somehow be solved via operations research and we have spoken about the few common ones that are used primarily.

Casino:

Operations Research in Casinos mainly focusses on Slot machines and the techniques involved in strategically enhancing the potential of the same. The industry in general derives most of its revenue from Slot Machines. Therefore, most of the focus pertaining to optimization in Casinos will cater to Slot Machines. Slot machines can be used in two formats, coin system and the member card slot machine. The backend of slot machines traces back to the production of slot machines. The introduction of Operations Research in Casinos starts with optimizing the slot floor

(Singh, 2010) The primary task for the casino operator is planning and deciding the mix of slot machines in order to maximize performance. This initiates the introduction of Operations Research in Casinos. It involves optimizing the casino slot floor as a linear programming problem. There are two approaches that can be taken to optimize the problem at hand.

Talking about the slot mix, it mainly consists of three main components, 1) floor configuration, 2) mechanical configuration and 3) model mix. Floor Configuration can be defined as the

different and strategic positions where the Slot Machines should be stationary on the floor. Mechanical Configuration pertains to the build and technical aspect of the machinery, the par/breakeven, hit frequency and other factors which need to be looked from a different perspective. Model Mix includes the different variety and number of models present of the Slot Machines since they have different pay back rates. Pay back rates generally vary from 85% to 98%. The pay back rate is calculated by denomination. The higher the denomination of the slot machine, the higher is the pay back rate. For a Penny Machine, the pay back rate would be somewhere from 87%-90% which is considered to be low. If suppose the \$25 machine, the pay back rate will be relatively higher and somewhere around, 95%-98%.

The incorporation of linear programming in Casinos can be done in the following way. Linear Programming is the use of the mathematical model which is incorporated in the working of slot machines. Linear signifies that all the functions in the model must be linear functions. The form in which Programming is incorporated is in terms computer programming which is done in the Slot machines. This procedure is carried out in an attempt to arrive at an optimal solution to the problem at hand.

(Singh, 2010) The mention of linear programming is also done in the form of comparison with the applications in retail sector pertaining to allocations of different compartments in the retail store in order to maximize space utilization along with consumer psychology which plays a major role. There has been speculation regarding slot machines closer to the entry gates of casinos to shell out more coinage, but it solely depends on the strategy of the casino and the placement of various other machines in the casino.

Football:

Football as a sport is becoming popular day by day and so is the application and use of operations research in it. Many of us football fans enjoy watching football matches, but we are unaware of the massive amount of work that is put in to organise a well-planned tournament. Operations research plays a major role in making this happen. It helps in designing goal lines, goal posts, deciding the win or lose probabilities, deciding the team fixtures, the weather predictions and most importantly minimise the overall cost of the tournament or of the football event being organised, so that with minimum amount of resources the most efficient outcome can be achieved. As Thomas j. Peter quotes, "Almost all quality improvement comes via simplification of design, manufacturing, process and procedures" with this I would like to highlight certain findings in this field. There are many studies that have been conducted in this field and the first type of problem that one faces while designing a tournament is the scheduling or making team fixtures. (Duran, 2012), Duran in his paper aims at finding OR techniques for football match scheduling. This study explains the geographic challenges and restrictions. In this he specifies the scheduling problem and explains how it can be solved using a technique called "Integer Linear Programming" (ILP). This method defines when and where will each match be played, which then generates the 'home-away' patterns and assigns them to the participating teams. Chilean league officials

have successfully used this model to schedule all five second division tournaments between 2007 to 2010, replacing the random selection method. (Rasmussen and Trick, 2008), the European journal for operations research, where V. Rasmussen tries to solve the problem of scheduling through round-robin scheduling which is a survey conducted that mainly focuses on two main categories, break minimization and distance minimization. It is also used to determine the number of games in each tournament. The second type of issue arising in this field is the referee assignment. (Mesut Yavuz, 2008) in this report Mesut talks about the importance of assigning referees to the professional tournaments, here again the method of integer programming is used, another method used here is NP-completeness. Measuring the effectiveness of football teams is another field in which operations research plays a pivotal role, (ECONOMICS, 2000) in this report published by the economics department of Texas Christian University, the effectiveness and efficiency of football teams are measured by using talent and capabilities as input and points won and revenue as output and then evaluate and choose the best performing team out of all the teams. FIFA too uses many OR techniques, for instance, to determine the stadium size with the help of linear and non-linear programming. (Keith Goldner, 2012), here Goldner stresses on the use Markov's chain model to determine whether or not a goal can stretch a match to extra time and this method also evaluates the geographical and climatic conditions prevailing before the match, basis on which the match will be played. From the previous research and studies carried out we can conclude that the operations research techniques were used effectively and efficiently in almost all football tournaments especially the FIFA world cups, it helped in its smooth running, helped in minimizing the overall costs, planning the design of the stadiums, tournament schedules, the destinations and also the referee assignments. Even though there are various limitations associated with operations research as a subject but on the other hand it is one of the most versatile subjects, which can be used in numerous fields to find the best and optimal solutions.

Conclusion

We have come to the conclusion that Operations Research has enhanced and optimised the sports industry in a large way. Since, the sports industry is varied and large, optimisation and strategy development are key. We focused on two key factors, strategy and tactics and scheduling. Operations Research is fluid in nature and thus can be used in any sphere and situation. For example, the problem of target setting for an interrupted cricket match uses Operations Research. Operations Research in gaming and sports is the same and yet have different features. Commonalities occur as all sports see opportunity to increase efficiency and productivity and thus the identified problem is picked up and various techniques are used to resolve the same. All sports require scheduling and use Operations research for the same as they are inter-city tournaments on a large scale. Different, because the application of Operations Research differs amongst all sports. For example, in F1 racing the Operations Research is technically trying to bridge the gap between a machine and a human by reducing the time taken to change tyres during a race. On the same lines, in F1 racing Operations Research could have been used in the speed of the cars, or the torque required for turning etc. But, Operations Research analyses and all and thus comes up with the most optimum outcome. This same technique could not have been used for Cricket. This explains how beneficial the application of operations research is to the sports industry and how it can draw commonalities and differences at the same time.

Limitations

We faced a few problems when it came to finding research papers for the technique used for scheduling matches in terms of reducing travel time, exhaustion, cost and increasing popularity or playing home matches on the weekend etc.

We also wished we had a more extensive background about the subject where in we could have used and applied techniques or understood the techniques applied better and given suggestions or alterations for the same.

However, as a whole we think Operations Research in Sports and Gaming has wide scope and thus very few limitations that could hinder optimality.

Bibliography

- Bose, M. (2010). *Commonwealth Games 2010: failings of Indian approach there for all to see*.
- Estilla Lins, M. L. (n.d.). Olympics-Operations Research. *Wiley Encyclopedia of Operations Research and Management Science*, 2-3.
- F1 strategy and pit stops*. (n.d.). Retrieved from math scareers: <https://www.mathscareers.org.uk/article/f1-strategy-pit-stops/>
- Hemant Sangwan, D. K. (2015). Duckworth-Lewis Rule Based On Operation Research. *INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN TECHNOLOGY*, 1046-47.
- Kasra Christopher Ghaharian, A. S. (2011). A Mathematical Approach for optimising the casino slot floor: LPP. *UNLV Gaming Research & Review Journal*, 1-3.
- Rasmussen, R. V. (2007). *Round Robin Scheduling - A Survey*. Carnegie Mellon University.
- Singh, A. K. (2010). *A Mathematical Approach for Optimizing the Casino Slot Floor: A Linear Programming Application*. Las Vegas: Kasra Christopher Ghaharian 2011.
- SPURGEON, B. (2008, July). *Computers are Formula One's wizards of winning*. Retrieved from The New York Times: <https://www.nytimes.com/2008/07/04/sports/04iht-SRSTRATEGY.1.14234141.html>
- Sulsters, C. (2018, February). *Simulating Formula One Race Strategies*.
- Trick, M. (2011). *The Appeal of Operations Research and Sports*.
- Ursin, D. J. (2014). *A Markov Model for Baseball with Applications*. University of Wisconsin Milwaukee.
- Whittle, J. (2012, March). *The Game Theory of Formula 1: Winning the Monaco Grand Prix*. Retrieved from The game is a foot: <http://thegameisafot.weebly.com/guest-articles/the-game-theory-of-formula-1-winning-the-monaco-grand-prix>