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Applications of Operations Research in Sports

Viraaj Verma
vermaviraaj.8503@gmail.com
SVKM's Narsee Monjee Institute of Management Studies, Bengaluru, Karnataka

Harshil Chhajer
chhajerharshil30@gmail.com
SVKM's Narsee Monjee Institute of Management Studies, Bengaluru, Karnataka

Nidhie Lohia
nidhielohia@gmail.com
SVKM's Narsee Monjee Institute of Management Studies, Bengaluru, Karnataka

Ruheen Nagpal
riyanagpal2404@gmail.com
SVKM's Narsee Monjee Institute of Management Studies, Bengaluru, Karnataka

Rachit Jain
rachitjain483@gmail.com
SVKM's Narsee Monjee Institute of Management Studies, Bengaluru, Karnataka

ABSTRACT

The goal of the research paper is to identify various operations research techniques that are used in the sports industry to help with match scheduling, player performance evaluation for team selection, and development of a team formation that is effective for winning in sports like football, basketball, and cricket. It also demonstrates how certain tactics can assist us in developing stronger game plans for sports like tennis, badminton, boxing, and swimming. Finally, the techniques employed in the research paper have aided sports managers, coaches, and players in using an appropriate tool to resolve a number of issues in the sports sector.

Keywords *– Game Theory, Team Formation, Scheduling, Decision Making*

1. INTRODUCTION

Every time a badminton racket is picked, a table tennis ball served, a basketball dunked or a football goal scored, decisions are taken for which OR is relevant and, whether consciously or unconsciously, applied.

Sports have been in existence for more than 3000 years. It started out with throwing of spears and sparring one-on -one with opponents. But in the past 100 or so years the entire dynamics of sports have turned upside-down; sports such as javelin throw, long jump, relays, short put, swimming etc. have come into existence. With the existence of these sports there have been many researchers who have tried to examine the application of sports in different fields. One such field which we have chosen for examination of Sports is Operations Research.

The main objective of this paper is to get a better understanding of Operations Research in Sports. The various techniques and methods chosen, among many, are Game Theory, AHP (Analytic Hierarchical Process), TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), and Integer programming, Game Refinement Theory, Fuzzy Theory, Data Envelopment Analysis (DEA) and Scheduling of Timetabling.

2. LITERATURE REVIEW

Sports have been in existence for a long time and have existed everywhere and in many cultures. Many modern sports have a long history, whereas some have decades or even millenniums of development.

Over the years, Madison Square Garden, has hosted a considerable number of boxing matches and New York City ranks towards the top of any list of boxing cities due to its long history and heritage in the sport. [[1]]

An application of game theory can be seen in a boxing match between Ali and Foremen where Game Theory was used. The strategy adopted by Ali was "rope-a-dope" wherein he was purposely getting hit only in the arms and body and waiting for foremen to tire out so that he could win the match by a knockout. [[2]]

Basketball has a long history dating back to 1891, invented by James Naismith. It is the most popular sport in the United States, followed by the Philippines and Australia. [[3]]

Game Theory in Basketball helps to plan the offensive and defensive strategies and its result leads to different suggestions to both the teams for both kind of strategies with different combinations in a Game matrix. [[4]]

Tennis is said to have originated in the 12th Century. The Wimbledon Championships, the oldest and most famous tennis competition in the world, was first held in 1877. [[5]]
In Tennis an application of dominant strategy could be seen during the Australian Open 2009 men's singles where Roger Federer and Rafael Nadal faced off against each other. It gives an overview to which dominant strategy should be used by the players to win the game. [[6]]

The game of football began in Britain in the 19th century. It is one of the most well-liked sports in the world, and nations like France, Israel, and Italy have declared it to be their national sport. ([7])

Operations Research has been used in football to measure the effectiveness and performance of the team, elimination of teams, player selection and team formation. For these purposes various techniques such as AHP and DEA, Integer Programming Model, TOPSIS method and Fuzzy Theory have been used, respectively. [[8]] [[9]] [[10]] [[11]] [[12]] [[13]]

The Paralympics are a recurring series of international multisport competitions involving participants with various physical limitations. [[14]]

During the 2012 Paralympics, all the runners had a desire to win the race. All of them wanted to run slower at the beginning of the race and run faster towards the end of race. This dominant strategy was applied when the runner was close to the finish line and waited for others players to make their move so that they would not run out of steam. [[15]]

According to statistics, Badminton is played by more than 220 million individuals routinely. The origins of the sport can be found in ancient Greece, China, and India, and it shares a lot of similarities with the classic kids' games such as battledore and shuttlecock. [[16]]

Another application of game theory is Nash equilibrium which has been used in this study. The example taken was of a women's doubles match in 2012 summer Olympics, wherein both the teams wanted to lose so that they could face off against a weaker opponent, but this is not possible in reality. Hence, they were stuck in a Nash equilibrium under lose- lose situation. [[17]]

The second most popular sport in the world is cricket. It is enjoyed by more than 2.5 billion fans globally. The most popular countries for this sport are sub continental Asia (especially India and Pakistan), Australia, and England. ([18])

Timetabling in County Cricket (England) was shifted to a new method of making a Tabu Search to eradicate the pre-existing time-consuming process to reach the optimum solution with pre-evolved descent algorithm. It was followed by Intensification and Diversification with the gradual improvement of a solution subject to minor changes. [[19]]

Swimming was ranked as the second most popular sport activity in 2008. [[20]]

In swimming game theory shows its application in the form of dominant strategy. It describes a scenario in which one player has a better technique regardless of how the other players behave. [[21]]

Table tennis has become one of the most popular sports in the last decade. According to Top end Sports, 300 million individuals play table tennis worldwide. [[22]]

This game has seen a lot of changes in the last 100 years. For example- the diameter of the ball was increased, the width of the table was increased and the height of the net lowered etc. to measure whether these changes contributed to the sport becoming more popular, game refinement theory was used. [[23]]

3. ANALYSIS AND FINDINGS

As per our research it is found that Operations Research tools are used for various purposes in the sports industry, of which a few are mentioned below:

Team Formation and Player Selection

Football team formation is one of the most important tactics to provide a framework in player positioning. Choosing a wrong player might cost the football club millions of dollars and even the championship.

Fuzzy set theory is the strategy used for the purpose of decision making. A two-phase process was used for Parsan Soccer Club (PSC). The first stage was selection in which three coaches took 18 evaluation criterias. The top three combinations for the

defender's position were (5, 2, 7, 1), (5, 2, 7, 6), and (5, 2, 7, 4); for the midfielder's position, the top three combinations were (12, 14, 13, 8), (12, 14, 13, 9), and (12, 14, 13, 15); and for the forward position, the top three combinations were (18, 20), (18, 17), and (18, 19). The second stage was Arrangement of players using FIS. The goal of this step was to choose the ideal 4-4-2 formation configuration. The best defensive combination, as determined by the results of the previous phase, was (5, 2, 7, 1) using FIS. This shows the importance of the theory. ([8])

Another case was when the Coaches had conducted an Anthropometry Test and fitness test for players in one of the secondary schools in Malaysia and 25 active students between 15-17 years were selected. A technique under MADM method called TOPSIS was used to select the best attributes of a player by comparing the performance with the ideal and worst one. ([9])

The relevance of the Two-Phase strategy was demonstrated through a case study on the Turkish soccer club Fenerbahçe.

The first phase of the approach is AHP wherein they have created a model involving two steps:
1. Structuring the decision problem - They had created 6 goals such as Goalkeeper, Midfielders, Winger, etc. to get the players a position in the team. A hierarchical structure for solving goals had been made. The structure was called criteria and 20 such criteria were made, such as jumping, kicking, throwing, stamina, etc. to meet the goals and the player who satisfies the criteria's gets selected.

2. Pairwise comparison - After building the AHP hierarchy, they formed a team of experts which consisted of the Physical Education and Sports Schools who had expertise in football. They examined the criteria of players required to meet the goal for allotting a football position to players in the team.

In the second phase approach, a 0-1 integer linear programming model was developed called LINDO 14.0 which compared the attribute values of a player such as aerial ability, dribbling, stamina, teamwork, etc. and out of which top performers were selected. ([10])

Team Performance

In sports effectiveness of the team is useful for the investors to make an analysis about which team to invest in. It also helps the team owners to get a better understanding about the situation the team is in and develop a better understanding of the improvements that are to be done.

IPL 2009 data was considered in which DEA method was used. All expenses related to IPL are considered as a single input. On the other hand, teams total revenue, profit, points awarded in the league table, and net run rate were taken into consideration as the output. After all the calculations it was found that CSK, DD and RR are globally efficient. Among other IPL teams, RR was proficient because it managed to secure the highest profit with the fewest expenses. On the contrary, RCB was ineffective when compared to other teams due to its incredibly low profit and hefty costs. ([11])

It was interesting to know that for the same purpose a combination of two Operation Research techniques that is DEA and AHP was used. AHP instrument was utilized for aggregating the sub-factors which includes input-output factors, and then DEA was utilized for working out the effectiveness measure. The Iranian premier Football league 2009-10 data was used. The two inputs were - wages paid to coaches, players and staffs and the team's fixed assets. The three outputs were- at the end of the season points gained by each team, the total revenue of the season and spectator rate of attraction to the stadium. The analysis showed that Sepahan Football Club was the winner during this season. It had a good efficiency ranking, the reason behind this was that the coaches were paid twice than that of the other clubs. ([12])

Elimination of Teams

If a team doesn't make the playoffs, it loses a lot of money, and in some cases, it may even be forced to sell some of its best players to pay for upkeep.

Integer programming model was used to solve the above-mentioned problem. An example of Brazilian National Football championship was used which was organized in 2 stages. Two models were used to detect in advance whether the team would qualify or would it be eliminated from the playoffs. This model was used to solve GQP (Guaranteed qualification problem), which means that regardless of other outcomes, each team must win a minimum number of points to qualify. It was used in the second model, which was based on PQP (Possible Qualification Problem), where teams still had a chance to advance even if they tied for first place with other teams. In the Brazilian National Football after the 11th round, on September 15, Antonio Lopes, the head coach of Vasco da Gama told in a news conference that his team would qualify to the playoffs if it could win 10 of the last 14 games. However, the research contradicted his statement and proved that, even if the team won all of its remaining games, there were several possibilities that could have placed them outside the qualification zone. The two models that are suggested represent an inspiring application of operations research methods to the planning and management of sporting events. ([13])

Scheduling

Scheduling by Cricket authorities is important to timetable the county fixtures for every season which must satisfies all the parties involved. This was done to eradicate the pre-existing time consuming and difficult task.

Timetabling in County Cricket was shifted to Tabu Search to reach the optimum with pre-evolved descent algorithm. It was followed by Intensification and Diversification with the gradual improvement of solution subject to minor changes. Usually, this program was run overnight or possibly over a weekend together with the number of minutes to be spent on both the phases.
It allowed 125 and 7 iterations in Phase 1 and 2 respectively resulting in getting the best solution. ([19])

Strategies Leading to Better Outcomes
It helped in Basketball by creating effective offensive and defensive strategies via Game Matrix showing different suggestions.

A scenario was created in which Roger Federer and Rafael Nadal squared off against each other in the men's singles final of the 2009 Australian Open. Tennis players usually view serving as having the first move advantage since it gives them control of the court and puts greater pressure on their opponent. Federer was on the serving end, while Nadal was on the receiving end. For Nadal, a dominant strategy would be returning a linear ball. However, for Federer, the outer angle is the optimum option. (6)

Another example was a boxing match between Ali and Foreman. Given that Foreman's previous fights had all ended in knockouts, Ali believed that Foreman would enter the battle with great aggression. Ali understood that he had to be exceedingly cautious and play to his own strengths—his will and endurance—because he knew this was Foreman's dominant strategy. Ali came up with a plan that utilized his own skills while letting Foreman exhaust himself. ([2])

Runners competing in the Paralympics outperformed 2012 Olympic gold medalist Matthew Centrowitz Jr. People had assumed that the usage of blades by Paralympic runners was the source of their speedier times, however this was not the case for T12/T13 (Race format). In this race category, blades are not permitted in the competition. According to game theory, the players didn't choose to set a new record or to run the fastest time possible. Because no one wanted to move too quickly, the racers ran remarkably slowly together during the first three loops. The dominant strategy was to stay close at the front and wait to make his or her move not too soon for fear of running out of steam. Players began to sprint quickly over the final 100 meters of the race. ([15])

Another Sport in which application of Game theory can be seen is swimming. In the 2008 Olympics both Michael Phelps and Milorad Cavic were going head-to-head but the difference which resulted in the victory of Michael Phelps was that in the final lap instead of gliding into the wall he made a short stroke which resulted in his victory. He had already realized that in the final 5 meters Cavic would be next to him so based on his opponent's action which was gliding he decided to go ahead with his own dominant strategy and made a short stroke. This resulted in his victory by a margin of .01 seconds. ([21])

The badminton women's doubles team from South Korea and China at the 2012 summer Olympics made the decision to lose the match in order to play a weaker opponent and have a better chance of winning. Both teams' main plan of attack was to lose the game. The side that loses the first game will benefit more because they stand a better chance of winning the next round and moving on. The team that triumphs in the opening round will have a lesser chance of triumphing in the following round, which suggests that the team will receive a lower reward. Due to this, both participants are caught in a Nash equilibrium where they both desire to lose but this isn't possible in reality. ([17])

Sophistication and Attractiveness
The sport of table tennis has seen a lot of changes in the past 100 years. Some of these changes are the height of the net was reduced from 17mm to 15.25mm, the table was widened from 146.4mm to 152.5mm and the diameter of the ball was increased from 38mm to 40mm. This increase in the diameter of the ball increased the drag of the ball and reduced the rotation and velocity of the ball. These changes changed the entire gameplay of table tennis. Prior to these changes the players had a defensive approach but after the above-mentioned changes the game became fast- paced and the players started adopting different offensive strategies. This was done so that the game becomes more enjoyable for both the spectators and the players. However, a method was needed to measure whether these changes resulted in the game become more popular or not, this came in the form of Game Refinement Theory. Game refinement theory is a method which is used to measure the sophistication and the attractiveness of the game. This method also showed that the game of table tennis is highly dependent on skill rather than luck. ([23])

4. CONCLUSION

Operations Research is vital to the sports sector. It has been used extensively in sports for the past 50 years, and its use is only likely to rise significantly in the coming years. It is safe to state that it facilitates better decision-making in every area of a sporting event after examining its use in various sports. It is used to formulate successful strategies, plan different fixtures, and project tournament results. It analyses all factors and provides the best answer. Based on operations research, a team's strategy directly affects how well the team performs. Therefore, every choice must be carefully thought out and carried out.

Easily accessible on a screen that can be quantitatively analyzed. Operations Research has become an important tool in aiding players and team managers to prepare and perform more strategically.

5. LIMITATIONS

1. The current study done may not reflect the relationship between the dependent and independent variables used.
2. OR tools can be used to provide solution only when all elements related to a problem can be expressed in some quantity. Factors which can't be quantified, no matter how important they are for that case, will not be covered under OR tools.
3. Due to the human subject matter involved, implementing a decision made using OR techniques are a major undertaking in and of itself. Results from OR instruments may lead to several or modest alterations due to several psychological reasons.

6. RECOMMENDATIONS

1. We recommend the application of operations research be widened into sports which are not that well known and not that streamlined. Sports such as long jump, short put, sumo wrestling, water polo and many other sports have not been studied under operations research. By studying and analysing the application, the popularity of the sport in a way could be increased.
2. To increase our scope of research a wider base of sample could be used.
3. The TOPSIS method could be used for player selection in multi-player sport such as Basketball, Handball because the method helps in identifying the attributes required for selection and numerous criteria's can be added in it.

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