Evaluation on Sports Scheduling Model

Yanzhen Wang*

School of Tianfu, Chengdu, China

*Corresponding author: 3100400243@caa.edu.cn

Abstract. Sports competitions have gradually attracted people's attention. Various sports tournaments and round-robin are held throughout the world. During these competitions, programming tools play a vital role. Due to the popularity of sports areas, a large number of research about scheduling related to sports have done and many researchers have devoted themselves to this yield. However, there are still many problems to be solved, and many models still have room for improvement. This paper is based on one previous essay which study umpire scheduling, summarized and sorted out the content of this paper, and also proposed the advantages and disadvantages of this article, therefore exploring the direction of improvement of these scheduling models. The study found the mathematical model used is objective and logical, also simple to use but at the cost of neglecting the random and dynamic in reality. At the same time, the lack of analysis combined with first-hand data makes the model less convincing.

Keywords: programming; sports schedules; tennis.

1. Introduction

Sports competitions, as an activity with both entertainment and commercial properties, have gradually attracted people's attention as a result of the improvement in people's quality of life. Almost everyone knows that Argentina has won the 2022 World Cup. However, how many people know that a tournament or round-robin is also closely related to mathematics? In fact, from sports timetabling, to umpire scheduling and so on, none of them can do without the help of mathematical tools. The arrangement of time and place of the tournaments, the order of teams, the arrangement of opponents, and the arrangement of referees, etc., highly affect the efficiency and fairness of the game. As a result, sports scheduling problems are an area of increasing interest.

Tremendous research has been done in order to make these tournaments or round-robins operate smoothly. By using a hybrid method that combines Lagrangian relaxation and constraint programming in a hierarchical design, Bouygues eLab was able to solve the issues with the traveling tournament [1]. For both, an even number of teams that is not a multiple of four and an odd number of teams, D.C. Blest and D.G. Fitzgerald created balanced tournament designs [2].

Adam Farmer, Jeffrey S. Smith, and Luke T. Miller have developed an integer program scheduling model that automates the procedure of assigning and scheduling line umpires, which provided a schedule with high acceptance and need very little effort at the 2003 US Open [3].

However, no studies have been done for evaluating and improving these essays.

This paper will take “Scheduling Umpire Crews for Professional Tennis Tournaments” written by Adam Farmer, Jeffrey S. Smith, and Luke T. Miller [3] as the research object, summarizing the core arguments of the essay and evaluate them, giving follow-up researchers the direction of improvement, paving the way for further improving the model and thus improving the rationality and efficiency of sports event arrangements.

This paper will also introduce the main problems in sports scheduling, as well as the common programming model used in solving these problems. At last, this paper will describe the current state of the tennis industry and forecasts for the future.

2. Article Review

2.1 Article summary

2.1.1 Overview

At tennis tournaments, the process of assigning and scheduling line umpires usually requires manual operation by the chief umpire, and the software available nowadays often provides sub-optimal or even infeasible schedules.

To solve this problem, the authors developed a program that can automatically generate schedules with high quality continuously, requiring only 25% of the time spent by other approaches.

2.1.2 Background

The scheduling process needs to consider tremendous things, and different criteria are required when selecting head umpires and line umpires. This means that the scheduling process is very complicated.

In order to facilitate the scheduling process, the United States Tennis Association (USTA) developed a series of programs in the hope of assigning umpires automatically. This scheduling algorithm works by sequentially assigning the best available referees to the lines with the highest priority.

But it makes separated assignments and did not consider their impacts on the whole schedule, therefore often assigning too many high-skill-rating umpires to early courts. Also, the system did not regard gender requirements.

Various operations research tools have been developed for all kinds of scheduling, but no previous program meets all the constraints and objectives of tennis-umpire scheduling, so we cannot directly apply any previous solution approach to this problem.

2.1.3 Purpose

The objective of this program is:

minimize the weighted deviation between assigned skill ratings and target skill ratings for each location, within specific constraints.

There are three main constraints. First, during one session, each umpire can be assigned only once. Second, each crew is required to have the appropriate number of umpires, and each umpire is required to meet the necessary qualifications for his or her position. Finally, gender feasibility must be maintained within each crew.

2.1.4 Methodology

The authors first developed an integer-programming formulation by coding the integer program in AMPL -- a kind of modeling language -- and solving it through CPLEX optimization software.

The integer-programming formulation operates by assigning umpires with a lower skill level to lines with positive assignment weight factors and assigning umpires with a higher skill level to lines with negative assignment weight factors, where assignment weight factors measure how far the assigned skill rating deviates from the target skill rating.

Later, the USTA asked for eliminating the application of CPLEX, therefore a two-phase heuristic is developed. Firstly, by using the semi-sequential approach, an initial set of referee assignments is built. In this process, umpires are assigned in the order of decreasing skill level(the worst will be assigned first), so as to minimize the infeasibilities related to skill rating. And the heuristic's construction aims to satisfy all gender requirements at the start due to the difficulty in maintaining gender feasibility. Secondly, the initial referee assignment set is enhanced by a simulated-annealing algorithm. It is found that the heuristic produces schedules whose objective values are as exact as those found using CPLEX.

2.1.5 Result

The developed umpire scheduling tool for tennis tournaments is simple to use.

The program has several improvements to the USTA's system, including minimizing discrepancies between referee's skill rating and minimum desired rating for specific court positions, meeting gender requirements as much as possible, as well as providing the head umpires flexibility, which means they can manually assign line umpires while guaranteeing the optimization of the remaining tasks. By replacing the existing manual system with the umpire-crew-scheduling tool, USTA was able to save 68% to 91% of its time.

Also, USTA officials have confirmed that the workaround provides a highly acceptable schedule with minimal effort.

2.2 Remark

This paper has used a mathematical model, which makes the result more objective and logical. Also, the algorithm is relatively simplified, using only a few formulas, which are easy to understand and simple to use.

At the same time, the paper has Incorporated a mathematical model with real-life cases. Combining theory with practice effectively highlights the contribution of the article.

However, the model is relatively simple and only uses linear programming, so the influence of dynamic and randomness is not considered. Most problems, in reality, are dynamic and random, but the model ignores them in order to simplify the real situation.

The problem with the linear programming model is that it is essentially a static model. But in reality, some indicators in the objective function are often not constant as the constraints change. For instance, when designing the scheduling method, the skill ratings of umpires are essentially a variable that cannot be absolutely static according to their training and experience, which will inevitably result in changes in the ideal model. On another hand, each index in the constraints may also show dynamic changes. Generally speaking, the linear programming model is relatively mechanical, which determines its inevitable limitations.

In real life, much information about decision-making tasks does not appear all at once but comes sequentially over time. For example, when making stock investment decisions, stock prices appear sequentially over time, and you have to decide whether to sell or buy after each price appears. Every time you make a decision based on the principle of maximizing profit, you really want to know which prices will appear later. Therefore, you will adopt a strategy of watching and waiting for the best price to appear. In this process, you need to "decide" when to stop watching the stock price and when to sell or buy. Generally speaking, the situation in which the alternatives appear in order is called dynamic decision-making, while the situation in which all the alternatives appear at once is called static decision-making [4]. So, it is clear that most decision-making processes in real life are dynamic.

Furthermore, this article does not use questionnaires for actual data research. A questionnaire survey can obtain first-hand data to acquire more objective, extensive results, making the essay more convincing. The paper can be compensated from this point of view in the future.

3. Discussion

3.1 Common Programming Model

The scheduling model used in the research subject paper is an integer-programming model.

Integer programming is a powerful instrument for modeling and solving schedule problems. Directly applying an integer programming solver to the model can handle many scheduling issues in round robins or tournaments.

There are many other approaches that are common when handling optimization problems in sports scheduling, such as decomposition, constraint programming, and metaheuristics.

3.1.1 Decomposition Approaches

Decomposition means decomposing the problems into sub-problems and then solving these sub-problems sequentially by certain algorithms.

Decomposition consists of two parts, that is, pairing the participating teams(schedule), and building the competition pattern(break). So, there are two main approaches:

(1) schedule and break:

Pair the teams to identify their rivals, and then determine the corresponding home-away pattern for the paired teams.

(2) break and schedule:

First, determine a feasible home-away mode, and then fix the corresponding mode for each pair.

In a “schedule and break” approach, there is a sub-problem to find a home-away pattern corresponding to the pairing determined previously while trying to minimize the number of breaks of the pattern.

After converting the break minimization problem into a maximum cut problem in an undirected graph, Matthias Elf, Michael Ju, and Giovanni Rinaldi used a branch-and-cut algorithm to solve the problem [5].

In a “break and schedule” approach, finding a workable opponent schedule for the given home-away pattern is a sub-problem.

In order to determine if a round-robin tournament can be organized with a particular HAP set, Dirk Briskorn uses integer linear algebra and provides a necessary condition for feasibility [6]. This condition is demonstrated to be strictly stronger than those offered by Miyashiro et al [7].

3.1.2 Heuristic Search and Metaheuristics

Many schedule optimization issues are computationally difficult due to a lack of usable algorithms. Although some sports scheduling issues can be precisely solved with integer programming because of their small size or intrinsic structure, this is not always the case. Therefore, heuristic algorithms, or in another word, approximate algorithms, which find a sub-optimal solution within a reasonable computational time, are often chosen in practice.

Finding pathways through graphs was a challenge that Peter E. Hart, Nils J. Nilsson, and Bertram Raphael solved by incorporating heuristic data from the issue area into a formal mathematical theory of graph searching [8].

3.2 Other Objectives in Sports Scheduling

3.2.1 Break Minimization

Minimizing breaks, or at least keeping them balanced, is one of the most significant scheduling objectives in the sports area.

According to Forrest and Simmons (2006), scheduling consecutive home games has a damaging effect on attendance. An ideal alternation of home and away games is therefore preferred for each team. But the majority of the time, teams will play two consecutive home games or two consecutive away games, which is referred to as a "break"[9].

For a given round-robin tournament schedule, Ryuhei Miyashiro and Tomomi Matsui have presented a polynomial-time approach to determine an equal home-away assignment. The findings provide a solution to a conundrum regarding the computing difficulty of the break minimization problem in sports scheduling[10].

3.2.2 Carry-over Effects Minimization

If there are multiple teams that first compete with team A and then immediately compete with team B, then team A can be said to have a carry-over effect on team B.

At this point, if team A is a strong team, then team B may be at an advantage compared to the other teams because a team that has just played against a strong opponent is likely to be very tired in the next game. And vice versa.

In a round-robin competition, decreasing the value of the carry-over effect is a challenge that Ryuhei Miyashiro and Tomomi Matsui address. They suggested a straightforward approach to creating schedules with less carry-over effect rapidly [12].

3.3 Tennis Industry

3.3.1 Current state--Tennis experienced a boom in 2021

According to USTA, the tennis industry had a sharp rise in participation and equipment sales in 2021, marking the second year in a row that this trend has been observed. (Figure 1, Figure 2).

Tennis has had a 27.9% growth in participation over the last two years (from 2019 to 2021), with an increase of over 4.9 million players during that time. And almost 40% more entry-level racquets were sold overall (https://www.sportsdestinations.com/sports/tennis/tennis-shows-promising-growth-22422).

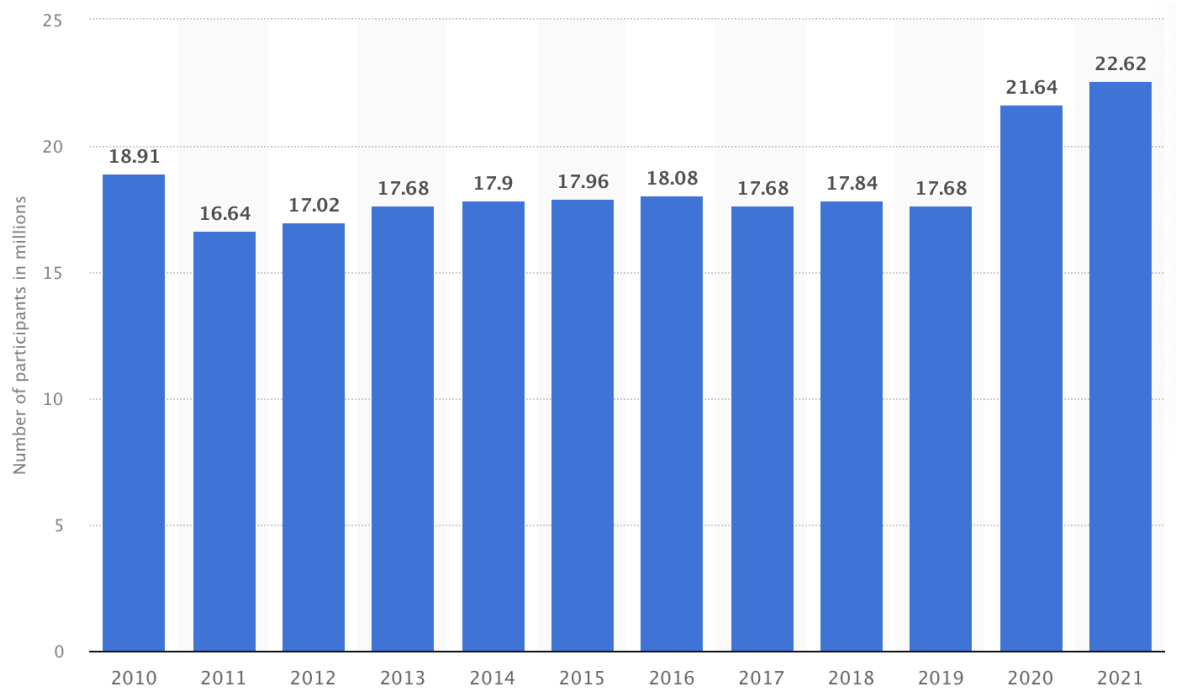

Figure 1. Number of participants in tennis in the United States from 2010 to 2021(in millions) (https://www.statista.com/statistics/191966/participants-in-tennis-in-the-us-since-2006/)

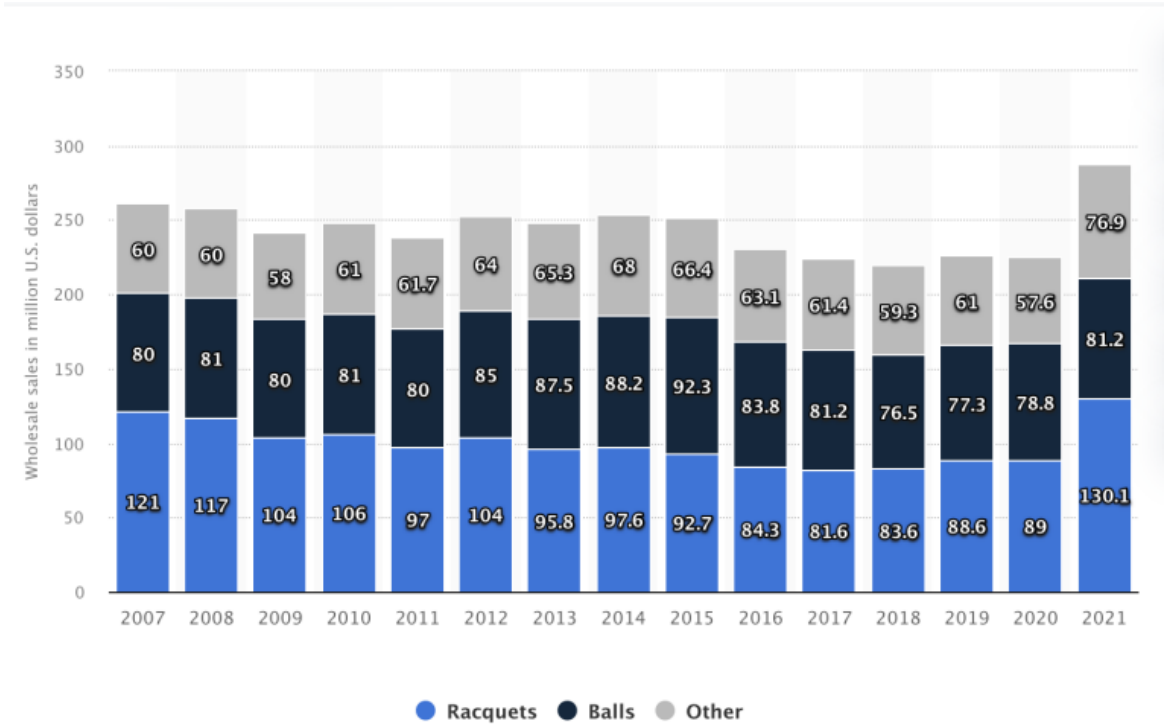

Figure 2. Tennis equipment wholesale sales in the U.S. from 2007 to 2021 (in million U.S. dollars) (https://www.statista.com/statistics/258666/tennis-equipment-wholesale-sales-in-the-us/)

According to Craig Morris, Chief Executive, of Community Tennis, USTA, "many people turned to tennis during the pandemic, and it is tremendously encouraging to see that the sport was able to capitalize on this momentum and continued to enjoy growth in 2021."

3.3.2 Forecasts for the Future

During the previous COVID-19 sanitary crisis, tennis entities faced major challenges as they had to suspend planned events and competitions.

In such a situation of high uncertainty, the tournament's ability to adapt to all possible new scenarios will be a key survival factor. During the duration of the crisis, sports entities need to embrace innovation and reinvent themselves in order to keep themselves alive.

As a result, there has been a significant rise in the development of eSports (electronic sports) over the past few years, and these types of virtual activities have shown very positive results in improving fan engagement during quarantine, especially among younger generations.

Now, COVID-19 is basically over. But the changes that took place in the tennis industry during the pandemic may remain, or the tennis industry may be permanently changed as a result.

However, virtual tournaments cannot provide the experience and excitement that live tournaments do provide. Therefore, in the future of the tennis industry, the digital world possibly will be a complement to, but not a substitution for, the physical world.

In conclusion, the future will offer new opportunities for the tennis industry, but it will also bring new challenges, which will lead to a different picture than our present. In the coming future, a tennis company's ability to adapt to the changing environment and innovate will be key success factors, and digital transformation will also be a key factor for success moving forward.

4. Conclusion

The scheduling model used in the research object paper is relatively simple and only applies linear programming, ignoring the dynamic and random in the real world. At the same time, the object paper does not combine the real data to analyze the model, which makes the model very abstract. Later

researchers could take dynamic and random into account when designing models, and questionnaires could be used to acquire first-hand data.

Also, according to the object paper, umpire-workload issues could be incorporated into the model as constraints, such as setting up a ceiling number of consecutive sessions an umpire could work on one court. Furthermore, it might be possible to develop a model which could determine the rotation schedules and distribute umpires concurrently, therefore, maximizing overall quality. And reduce the number of umpires utilized or making the best use of the existing umpires while still achieving the workload requirement could be another goal.

Decomposition, heuristic search, and metaheuristics are common programming approaches that can be used in future development.

In recent years, the tennis industry has experienced a boom, but in order to survive and develop well in the coming future, the ability to innovate will be the key factor. Also, esports may play an important role in the tennis industry.

The main contribution of this paper is:

(1) Summarized the vigorous development and promising future of the tennis industry, confirmed the future profitability of the tennis industry, thus providing context for subsequent research on the tennis industry, and pointed out the challenges that the industry may face in the future.

(2) Pointed out the direction and laid the foundation for subsequent research about the umpire-scheduling model for a professional tennis tournament.

However, the the boom of tennis industry may have some internal connection with the success of designing sports scheduling models. Later interested researchers can investigate this possible link.

References

[1] Benoist, T., Laburthe, F., & Rottembourg, B. (2001, April). Lagrange relaxation and constraint programming collaborative schemes for travelling tournament problems. In Proceedings CPAIOR (Vol. 1, pp. 15 - 26).

[2] Blest, D. C., & Fitzgerald, D. G. (1988). Scheduling sports competitions with a given distribution of times. Discrete Applied Mathematics, 22 (1), 9 - 19.

[3] Farmer, A., Smith, J. S., & Miller, L. T. (2007). Scheduling umpire crews for professional tennis tournaments. Interfaces, 37 (2), 187 - 196.

[4] Payne, J. W., Payne, J. W., Bettman, J. R., & Johnson, E. J. (1993). The adaptive decision maker. Cambridge university press.

[5] Elf, M., Jünger, M., & Rinaldi, G. (2003). Minimizing breaks by maximizing cuts. Operations Research Letters, 31 (5), 343 - 349.

[6] Briskorn, D. (2008). Feasibility of home–away-pattern sets for round robin tournaments. Operations Research Letters, 36 (3), 283 - 284.

[7] Miyashiro, R., Iwasaki, H., & Matsui, T. (2003). Characterizing feasible pattern sets with a minimum number of breaks. In Practice and Theory of Automated Timetabling IV: 4th International Conference, PATAT 2002, Gent, Belgium, August 21-23, 2002. Selected Revised Papers 4 (pp. 78-99). Springer Berlin Heidelberg.

[8] Hart, P. E., Nilsson, N. J., & Raphael, B. (1968). A formal basis for the heuristic determination of minimum cost paths. IEEE transactions on Systems Science and Cybernetics, 4 (2), 100 - 107.

[9] Goossens, D. R., & Spieksma, F. C. (2012). Soccer schedules in Europe: an overview. Journal of scheduling, 15, 641 - 651.

[10] Miyashiro, R., & Matsui, T. (2005). A polynomial-time algorithm to find an equitable home–away assignment. Operations Research Letters, 33 (3), 235 - 241.

[11] Kendall, G., Knust, S., Ribeiro, C. C., & Urrutia, S. (2010). Scheduling in sports: An annotated bibliography. Computers & Operations Research, 37 (1), 1 - 19.

[12] Miyashiro, R., & Matsui, T. (2006). Minimizing the carry-over effects value in a round-robin tournament. In Proceedings of the 6th International Conference on the Practice and Theory of Automated Timetabling (pp. 460-463). PATAT.