Assigning referees to a Chilean football tournament by integer programming and patterns

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Abstract The referee assignment in real-world sport competitions can lead to a hard combinatorial decision problem when a number of conditions must be taken into account, such as fairness and operational considerations. In practice, the assignment is often carried out manually by a group of experts, based on poorly defined criteria. Recently, a number of sports scheduling articles have focused on improving this task, by developing different models and solution approaches.

In this talk, we study a referee assignment problem in the Chilean football context. The main parameters are a tournament and a set of referees. The tournament is a set of games scheduled in a given number of rounds. Every game is played by two teams in a venue known beforehand. Every game is refereed by a "main referee" (or just "referee"), usually supported by two "assistant referees". The problem consists of assigning main referees to the games, fulfilling a number of conditions which have been defined together with the managers in charge of the referee assignment in the Chilean Football Association. These conditions intend to add transparency, objectivity and fairness to the assignment decision. They include: balancing the total amount of games refereed by every referee, balancing the number of games a referee is assigned to a same team, balancing the travel distances of the referees and taking into account their experience to referee special matches (e.g., the Association prefers to assign the most experienced referees to the matches played by *classic* rivals). We propose an integer linear programming model to tackle this problem.

The natural formulation of this referee assignment model can be solved by using standard computer solvers. However, large instances may lead to relatively long solution

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times, an undesirable matter for practical use. The current tournament of the Chilean First Division League consists of 21 teams that play 420 games distributed over 42 rounds. There are 16 referees, who can be assigned to these games. The IP model for this tournament contains about 6,700 variables and 10,000 constraints. Normally, the managers of the Association would like to analyze different instances of the problems in relatively short times. Furthermore, though at the beginning of the season they require us to find a solution to assign the referees to all the games of the tournament, they can also ask us to modify the assignment round by round, based on unexpected facts such as a temporary non-availability of a given referee. They expect us to solve every instance in a matter of minutes.

We have developed a solution approach based on patterns, inspired in the well-known home and away pattern procedures that have been successfully utilized in a number of articles aimed at scheduling sport games. While in the scheduling of games the patterns indicate if a team plays at home or away (or if it is bye) in each round of the tournament, the patterns we implement for the referee assignment indicate the set of games to which a referee can be assigned in each round. Given the particular geography of Chile, a very long and narrow country, we define these sets of games based on the location of the venues where they are going to be played. Any other arbitrary criteria to define the sets may also be suitable. Our solution methodology consists of two stages. In the first stage, we generate the patterns for each referee by solving an IP model that considers some of the constraints of the original problem. In the second stage, we implement another IP model that incorporates the rest of the conditions and assigns the referees to the games of the tournament. To the best of our knowledge, this work is the first one developing an approach based on patterns to solve a referee scheduling problem.

We implement the model for real instances of the problem and report results that improve the traditional assignment significantly. For instance, while the traditional assignment in the last tournament (generated manually) exhibits relatively large differences in the number of times a referee is assigned to games where one or another given team played, our assignment balances these amounts. Furthermore, by using the patterns-based approach we obtain a solution in a couple of minutes, while by running the natural formulation of the model it takes up to an hour (in both cases, we use an up-to-date computer and the solver CPLEX).

Currently, we are working together with the managers of the Chilean Football Association, evaluating the suitability of this referee assignment methodology for its real use in their 2010 professional and young divisions tournaments. By using our approach, the managers intend to stop receiving complaints from the teams on the referee assignment, a matter they have faced in multiple occasions by using their traditional methodology.

We would expect a concrete application of this work to contribute to the state of the art in sports scheduling and the related practices in football and other sports. In fact, though the scheduling of games has shown a significant development in the last decades, the literature on applications of sports scheduling techniques in real-world referee assignment problems is still scarce.