A two-phase heuristic approach to English football fixture scheduling over the holiday period

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Abstract Efficient scheduling of constrained resources is an important practical problem in many areas, including sports scheduling [5]. Here we consider the problem of fixture scheduling in the English football league. Unlike the Travelling Tournament Problem [1] where it is possible to reduce the overall distance travelled by clubs during a season, due the relatively small size of England and the structure of the playing season, the total distance travelled by each club is fixed each season. Despite this, it is still possible to reduce the distance travelled during certain periods of a season. During the Christmas and New Year period, when travel disruption often occurs due to issues such as reduced public transport timetables, infrastructure maintenance activities and weather, it is preferable to reduce the distance required for players and fans to travel to matches. There are also a set of constraints on clubs who are not allowed to play each other, or play a home match on the same day during this period. In this talk, we consider the two objectives separately. Firstly the set of fixtures to be played will be decided. In order to minimise the travelling distance, we will present a new permutation-based representation, based on the well-known Travelling Salesman Problem [2]. Following this, the actual day each fixture is to be played on is decided in a separate phase using an approach based on graph coloring.

Keywords Sports Scheduling · Heuristics · Metaheuristics · Combinatorial Optimisation · Travelling Salesman Problem

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Proceedings of the 12th International Conference on the Practice and Theory of Automated Timetabling (PATAT-2018), Vienna, Austria, August 28–31, 2018

1 Background

The English football league consists of four divisions, currently known as the Premier League, the Championship, League One and League Two. The Premier League consists of 20 clubs, whilst the remaining three divisions contain 24 clubs each. During the Christmas and New Year period, a set pattern of fixtures must be defined for each club, containing one home and one away match on separate days (or two home and two away matches in seasons where an international tournament is taking place). This requires a total of 46 (or 92) matches to be scheduled, respecting a number of constraints.

In addition to the constraints that matches can only be scheduled between two clubs within the same division and that the same two clubs should not play each other twice, a set of *paired* clubs are defined. Paired clubs are typically located in close proximity to one another and should not play each other. Additionally, paired clubs should not both play a home match on the same day. In the case that this happens it is referred to as a *pair clash*. As some pairings include three or four clubs, it is impossible to satisfy all of the constraints and avoid clashes completely when generating a schedule. This provides a second objective in addition to reducing travel distance when addressing this problem; to reduce the total number of pair clashes within a schedule. There are also additional constraints on the total number of clubs based in London and Greater Manchester that are allowed to play home matches on the same day due to policing requirements. This problem has been addressed previously in a number of papers [4,3,6].

2 Proposed two-phase approach

Here we propose a two-phased approach, where the first phase aims to minimise the distance travelled and the second phase minimises the number of pair clashes across divisions. The relationship between this problem and the Travelling Salesman Problem (TSP), was mentioned previously in the work of Gibbs et al. [3]. However, they did not formulate the problem of minimising travelling distance as a TSP directly. We represent the solution as a directed TSP, where the vertexes are the locations of each club. An outgoing edge from a particular vertex indicates that a club will travel to the other vertex (club) connected by that edge. Subsequently, a Hamiltonian path in this graph defines a complete set of fixtures for a division, with one home and one away match for each club. Although this yields a total search space size that is identical to that of the search tree used by Kendall [4], using a permutation representation means we only have to search the space once for each two-day scheduling period, not twice as is the case in their approach. By setting the distance between the vertexes of each set of paired clubs to an unreasonably high value, we can discourage a search method from generating fixtures between paired clubs using this representation. As the maximum permutation length is 24 (for the three divisions with this number of clubs), results are gen-

erated using simple constructive techniques and well-known TSP solvers from the literature. Once the set of fixtures have been decided, a graph coloring based approach is used to minimise the number of pair clashes across divisions and ensure that the location specific constraints are respected. The vertexes along the Hamiltonian paths for each division are colored alternately, with one color representing whether that club plays a home or match as the first of their two fixtures. As this results in each division having two possible colorings, all possible combinations are checked to find the set of colorings which result in the fewest pair clashes across divisions. Results will be presented for real-world data, with comparisons made to both the previous work in the literature and the published set of fixtures used by the football authorities. As future work, we see this solution representation as a basis for addressing the multi-objective variant of this problem studied by [6] directly.

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