Optimizing the Schedule of a Basketball Championship

A Traveling Tournament Problem Approach

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1 Motivation

Scheduling a professional basketball championship is a challenging operational task involving logistical efficiency and competitive fairness. Each team must play every other team both at home and away, while respecting practical constraints such as limited rest days, avoidance of repetitive matchups, and reasonable travel requirements.

In real leagues, suboptimal scheduling may lead to excessive travel for some teams, competitive imbalance, and increased operational costs. This project addresses the problem of designing an optimized season schedule that minimizes the total travel distance of all teams while maintaining a balanced and realistic competition structure.

This problem is a real-world application of Operations Research methods and is closely related to the well-known Traveling Tournament Problem (TTP), a challenging combinatorial optimization problem with significant practical relevance in sports scheduling.

2 Method

We consider a league with n teams, each associated with a fixed home city. Distances between cities are computed using real geographic coordinates and the Haversine formula, resulting in realistic travel distances.

2.1 Graph Interpretation

The season structure is represented as a complete directed graph where each node corresponds to a team. For every unordered pair of teams (i, j), two directed edges are included: $i \to j$ represents a match played at team i's home venue, and $j \to i$ represents the reverse fixture. This guarantees an equal number of home and away games for every team.

Scheduling the season then corresponds to ordering these directed edges over time (rounds), while minimizing the total distance traveled by all teams.

2.2 Decision Variables

The problem is formulated as a Mixed Integer Program (MIP) with the following main variables:

- $x_{i,j,r} \in \{0, 1\}$: equals 1 if team i plays at home against team j in round r.
- $at_{i,v,r} \in \{0, 1\}$: equals 1 if team i is located in city v during round r.
- $travel_{i,r} \geq 0$: distance traveled by team i between rounds $r - 1$ and r.

2.3 Constraints

The model enforces the following constraints:

- **Double round-robin:** each ordered pair (i, j) with $i \neq j$ is scheduled exactly once over the season.
- **One match per round:** each team plays exactly one match per round.
- **No immediate rematches:** teams cannot face the same opponent in consecutive rounds.
- **Home/away balance:** the number of home and away games is identical for each team.
- **Limited consecutive home/away games:** no team can play more than a fixed number of consecutive home or away matches.
- **Location consistency:** the location variables correctly reflect match assignments.

2.4 Objective Function

The objective is to minimize the total travel distance over the entire season:

$$\min \sum_{i} \sum_{r} travel_{i,r}.$$

Distances between consecutive rounds and the final return to the home city are explicitly accounted for using linear constraints.

The model is implemented in Python using the PuLP optimization library and solved with the CBC solver.

3 Preliminary Experiments

Computational experiments were conducted on leagues of up to four teams, due to the combinatorial complexity of the problem. Teams are randomly assigned to real U.S. cities, and distances are computed using geographic coordinates.

As a baseline, we evaluated randomly generated schedules and computed their total travel distance. These baseline schedules exhibit large variability and often lead to unnecessary back-and-forth travel.

The optimized schedules produced by the MIP significantly reduce the total travel distance while respecting all structural constraints. The model successfully generates feasible and balanced schedules within reasonable computation times for small instances.

Additionally, per-team travel statistics confirm that the travel burden is fairly distributed across teams, illustrating the fairness of the optimized schedules.

4 Discussion

The results demonstrate that optimization-based scheduling can substantially outperform naive or random approaches. However, the model's complexity grows rapidly with the number of teams, which limits scalability when using exact MIP solvers.

There is an inherent trade-off between model realism and computational tractability. While additional constraints improve schedule quality, they also increase solution time. This highlights the importance of approximation methods or decomposition techniques for larger leagues.

5 Conclusion and Future Work

This project presents an optimization framework for basketball championship scheduling that integrates realistic travel distances, fairness constraints, and logistical considerations. The proposed MIP formulation effectively minimizes total travel distance while producing balanced and feasible schedules.

Future work includes scaling the model to larger leagues, exploring heuristic or metaheuristic approaches, and incorporating additional practical constraints such as rest days, broadcast considerations, or multi-objective optimization.

Contributions

Gabriel was primarily responsible for the formulation of the project texts and written deliverables, including the milestone and the final report. He also contributed to the conceptual modeling of the problem, the interpretation of results, and the overall structuring of the project.

Lucas was primarily responsible for the Python implementation of the project. His contributions include data generation, distance computation using geographic coordinates, formulation and implementation of the optimization model in PuLP, execution of computational experiments, and debugging and validation of the obtained schedules.

Code Availability

The full implementation of the project, including data generation, optimization model, and experiment scripts, is available at:
`https://github.com/lgoutodier/projet_opti_basket`