Integrando giras en torneos double round robing: modelos, heurísticas y un caso de estudio

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Abstract. Durante las últimas décadas, el uso de algoritmos de optimización avanzados para generar calendarios deportivos ha captado la atención tanto de la comunidad académica como de los profesionales del sector. Desde una perspectiva de gestión, la estructura de la competencia y el diseño del calendario de la liga representan decisiones estratégicas clave, con un impacto directo en los ingresos y otros indicadores relevantes. La Liga Nacional de Básquetbol de Argentina (LNB) ha atravesado una transformación significativa desde 2014, implementando un diseño de calendario basado en giras para reducir la distancia total recorrida por los equipos, abordando así una variante del conocido problema del torneo itinerante (Traveling Tournament Problem, TTP). Utilizando la LNB como laboratorio, en este trabajo consideramos un torneo de todos contra todos a doble vuelta en el que, en ciertas rondas conocidas de antemano, se pueden definir giras de una longitud dada con el objetivo de reducir la distancia total de viaje. De este modo, el calendario adquiere un formato más estructurado sin dejar de capturar los beneficios en términos de reducción de distancias generados por las giras. A nuestro entender, este problema no ha sido abordado previamente en la literatura relacionada con la programación deportiva. Metodológicamente, formulamos un modelo de programación lineal entera para construir el calendario. Con el fin de escalar a instancias reales, proponemos además una matheurística que descompone el problema en diferentes etapas. A través de extensos experimentos computacionales, evaluamos el comportamiento de los algoritmos sobre instancias sintéticas derivadas de benchmarks de problemas relacionados presentes en la literatura, y realizamos un análisis detallado sobre seis temporadas de la LNB. En general, los resultados muestran que nuestro enfoque reduce la distancia recorrida en la mayoría de las instancias y que esto se traduce en mayores ingresos bajo supuestos moderados de asistencia a los estadios, con incrementos que alcanzan hasta el 40 por ciento.

Keywords: planificación en deportes · traveling tournament problem · programación lineal entera mixta · heurísticas

Integrating tours in double round robin tournaments: models, heuristics and a case study

Abstract. During the last decades, the use of advanced optimization algorithms to generate sports timetables has caught the attention of both academics and practitioners. From a managerial standpoint, the competition's structure and the design of the league's schedule represent key strategic decisions with a direct impact in terms of revenue and other important indicators. Argentina's National Basketball League (LNB) has undergone a major transformation since 2014, implementing a tour-based schedule design to reduce the total distance traveled by teams by tackling a variant of the well-known Traveling Tournament Problem (TTP). Using the LNB as a laboratory, in this work, we consider a double round robin tournament where, in some rounds, known in advance, tours of a given length can be defined in order to reduce the overall travel distance. In this fashion, the schedule follows a more structured format while still capturing the benefits in terms of distance reduction generated by the tours. To our knowledge, this problem has not been considered previously in the related sports timetabling literature. Methodologically, we formulate an Integer Linear Programming model to construct the schedule. In order to scale to real-world instances, we further propose a matheuristic that decomposes the problem into different stages. Throughout extensive computational experiments, In addition, we evaluate the behavior of the algorithms on synthetic instances derived from benchmark from related sport scheduling problems from the related literature and provide a detailed analysis over six LNB seasons. Overall, the results show that our framework reduces the traveled distance in most of the instances and that it translates into higher revenue under moderate stadium attendance assumptions, with increments reaching up to 40 percent.

Keywords: sports scheduling · traveling tournament problem · mixed integer programming · heuristics

Within organizational aspects, scheduling problems have caught the attention of the Operations Research (OR) community, in particular the design of fixtures and schedules for sport leagues. The structure of a tournament depends on several factors. The teams can be considered as a unique group, or can be partitioned into the so-called conferences, usually grouping teams according to their geographical location. Sometimes conferences are further partitioned into divisions. Classical formats for the tournaments are round robin fixtures (usually single or double round robin), where teams play against each other team the same number of times.

The schedule is organized in rounds, also called time-slots, where games among teams take place. A schedule is temporally constrained, or also referred

as compact, if each team plays exactly one game per round. For instance, most soccer leagues around the world follow this format, where a round is usually defined by the games played on a weekend. However, this constraint can be relaxed by considering a larger number of rounds, usually referred as temporally relaxed schedules, where the fixture for a team has several rounds with no games scheduled. A team could play multiple games within a short period of time, without the need of returning home in between, creating a tour. The well known Traveling Tournament Problem (TTP) (see, e.g. (Easton, Nemhauser, & Trick, 2001)) can be framed within this category. This flexibility enables to improve some quality metrics of the schedule, such as reducing the distance travelled by the teams by scheduling consecutive games on the road (tours) to reduce the travelled distance.

Research in this area is quite extensive. One stream of research is motivated mainly by concrete applications, where the objective is to find a feasible schedule to a real practical problem. In general, feasibility rules and business constraints are very dependent on the sport, the characteristics of the region, the traditions within the league, just to name a few. As a result, the problems considered and the resulting models are very rich, including plenty of domain specific characteristics. Another stream concentrates in the construction of the timetables, which also stands as a challenging computational problem motivating many papers dealing with theoretical, algorithmic and modeling developments. The specific characteristics imposed to the schedule impacts on the structure of the underlying problem, resulting in a family of difficult and interesting optimization problems related to sports scheduling.

From a managerial standpoint, a competition's structure and the design of a league's schedule represent key strategic decisions with a direct impact in terms of revenue and other important indicators. Current research is mainly devoted to tackle specific real-world cases and to provide methodological improvements for these particular problems. To the best of our knowledge the literature providing algorithmic comparisons or evaluating the impact of different league structures is rather scarce (see, e.g. (Kendall, Knust, Ribeiro, & Urrutia, 2010), (Durán, 2021)).

The Argentina's National Basketball League (LNB) has undergone a major transformation since 2014. Briefly, the LNB's regular season shifted from a 16-team tournament divided into two conferences in 2013-14 to a single-conference double round-robin touring system from the 2017-2018 season on-wards, as described in (Durán, Durán, Marenco, Mascialino, & Rey, 2019). In this paper, we build upon this experience and investigate the impact of considering an alternative league design, combining compact schedules and ideas from the TTP in a single schedule, where defining which games are to be considered for each format becomes part of the decision.

We consider the following methods:

1. An ILP model to solve the integrated problem.
2. A matheuristic that separates the problem in two stages: (i) formulate an ILP to determine the tours, and (ii) define the remaining of the schedule. To

scale to real instances and accelerate computations, we consider a couple-based system to reduce the size of the instance and incorporate inequalities from (Siemann & Walter, 2022) into (i) to improve the LP bounds.

3. The matheuristic 2 may induce a large number of breaks and increment the carry-over effect. Therefore, we develop a post-processing phase following the ideas proposed in (Rosati, Petris, Di Gaspero, & Schaerf, 2022) to explore neighboring improving solutions.

Overall, the results show that our framework reduces the traveled distance in most of the instances and that it translates into higher revenue under moderate stadium attendance assumptions, with increments reaching up to 40 percent.

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