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# Scheduling the professional Ecuadorian football league by integer programming

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ABSTRACT

A sports schedule sets the dates and venues of games among teams in a sports league. Constructing a sports schedule is a highly restrictive problem. The schedule must meet constraints due to regulations of a particular sports league federation and it must guarantee the participation of all teams on equal terms. Moreover, economic benefits of the teams and other agents involved in this activity are expected. Until 2011, the Ecuadorian football federation (FEF) had developed schedules for their professional football championship manually. In early 2011, the authors presented to the FEF authorities evidence that the use of mathematical programming to create feasible sports schedules could easily exceed the benefits obtained by the empirical method. Under this premise, this work presents an integer programming formulation, solved to optimality, for scheduling the professional football league in Ecuador, and also a heuristic approach based on three-phases for its solution. The schedules obtained met the expectations of the FEF and one of them was adopted as the official schedule for the 2012 edition of the Ecuadorian professional football championship.

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## 1. Introduction

Football is widely considered the world's most popular sport: according to a FIFA survey, 270 million people, which represents 4% of the world's population, actively participate in football, and Ecuador is no exception.

From the economic point of view, football is a source of direct and indirect employment and the amount of money handled in this sport is very high. Football teams, players, broadcasters, sponsors, clothing chains, informal trade, among others, are the agents involved in this activity. On the other hand, football as a sporting event is of great importance, from the cultural, as well as recreational point of view.

Designing a schedule in a soccer tournament is a fundamental issue. Without doubt, the schedule has an impact on each one of the aforementioned economic agents, who hope to obtain maximum economic benefits in each season. This will be achieved if the tournament provides exciting matches for the fans in appropriate schedules to improve stadium attendance. Moreover, the schedule must meet basic and special conditions of the championship, coordination with international events, security constraints, geographical constraints, etc. Accomplishing such objectives is an ambitious goal and the strategies to achieve them are largely subjective and difficult to determine. However, the vast literature on sports scheduling shows great progress towards achieving these goals. In [1], an introductory review of fundamental problems, formulations, and applications of optimization methods in sports scheduling, is provided. In [2] a framework for a highly constrained sport scheduling problem is introduced, and Kendall et al. [3] offer a complete annotated bibliography on the topic. In [4], an overview of the competition formats and the schedules used in 25 European soccer competitions for the season 2008–2009 is provided. In the Latin American case, in [5], the authors present an integer programming approach for scheduling the first and second division of the Brazilian football tournament, which is an extension of [6]. In [7], integer programming is used to schedule the Chilean football league, and improvements to their solution approach have been proposed in [8]. The 2010 professional soccer tournament in Honduras was scheduled, for the first time, using an integer programming model which is presented in [9].

In this paper, the design of the schedule for the professional football tournament in Ecuador has been addressed using mathematical programming techniques. First, an integer programming formulation is presented, which is solved to optimality on a free as well as a commercial software. On the other hand, an alternative three-phase heuristic approach is derived, based on the scheme proposed in [10] for a basketball league. This decomposition technique has been used for other leagues, as reported in [5,11–13].

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The paper is organized as follows. In Section 2, the problem and its peculiarities are stated. In Section 3, the integer programming formulation is presented. In Section 4, the heuristic approach is explained. In Section 5, some computational experiences are reported and, finally, Section 6 contains concluding remarks.

One of the optimal schedules of this project was submitted for approval to the Ecuadorian football federation (FEF) under the auspices of the football association of Pichincha province (AFNA). It must be noted that, under the regulations of the FEF, only the provincial football associations or the teams may submit calendars for evaluation. Among several options, the schedule proposed in this project was chosen by the FEF as the official schedule of the 2012 Ecuadorian professional football championship, series A.

## 2. The problem and its conditions

The first division of the Ecuadorian professional football league is divided into two categories, the A series and the B series. Each of them is composed of 12 teams playing under the same rules. In this paper we focus on the problem of generating a schedule for the A series, but the results have been applied to the B series as well.

By regulations of the FEF, the A series championship must meet several conditions. First, it must be played in three phases. In the first and second phases, the $n=12$ teams play a double round robin tournament, i.e., the phase is again divided into two stages, where team $X$ plays against team $Y$ once at its own venue (home game) in the first stage, and once at team $Y$'s venue (away game) in the second stage. Something peculiar to the Ecuadorian tournament is that the second stage of a phase is an "inverted mirror schedule", because the games in this stage are exactly the same as in the first stage but in reverse order and with reversed venues. That is, if team $X$ plays at its venue with team $Y$ in round $k$, then these two teams meet again in the second phase in round $2n-k-1$, but now playing at $Y$'s venue. Knowing this, note that the first two phases of the Ecuadorian football championship are *inverted mirror double round robin* tournaments involving $n$ teams playing in $2(n-1)=22$ rounds, divided into stages. The 22 rounds are set by the FEF and occur mostly on weekends, and occasionally on Wednesdays. In the third phase, the teams positioned in the first place of the first and second phases, respectively, play two matches to determine the champion of the tournament. If a team repeats the first position in the first two phases, it will automatically become the tournament champion.

On the other hand, FEF regulations stipulate that the schedules for the Ecuadorian football league must be evaluated by the FEF's Executive Committee, based on the following criteria: the teams must play in sequence as locals (home game) and visitors (away game). The provincial associations with two or more teams will have home games every round and those with just one team, when possible, once every two rounds. Observe that the last regulation can be extended by considering an equilibrium criterion: provincial associations with two or more teams will have home games every round with exactly half of the teams playing at home for even groups, and at least the smallest following integer of the half of the teams for odd groups. For the FEF authorities it is desirable that when a team repeats away games, one of these matches be held at the venue of a team from the same provincial association. The latter is the main measure of quality for schedules, i.e., the schedule with the largest number of such events is considered the best one.

As mentioned in the previous section, schedule proposals can be submitted for approval by provincial associations or teams. The proposals must be made by identifying the teams of each provincial association with the first letter of its province, followed by its ordinal number. The FEF's Executive Committee, after selecting one of the proposals, receives the list of teams from the provincial associations, with the ordinal number assigned in the schedule. The last requirement is prepared in advance by each provincial association, either by agreement among its teams or otherwise chosen at random.

**Table 1**
Provincial associations and their teams.

| Group | Province | Notation | Teams in a group |
|---|---|---|---|
| 1 | Pichincha | $\{P_1,P_2,P_3,P_4\}$ | Deportivo Quito<br>El Nacional<br>Independiente<br>Liga de Quito |
| 2 | Guayas | $\{G_1,G_2\}$ | Emelec<br>Barcelona |
| 3 | Tungurahua | $\{T_1,T_2\}$ | Macará<br>Técnico Universitario |
| 4 | Azuay | $\{A_1\}$ | Deportivo Cuenca |
| 5 | Chimborazo | $\{CH_1\}$ | Olmedo |
| 6 | Loja | $\{L_1\}$ | Liga de Loja |
| 7 | Manabí | $\{M_1\}$ | Manta |

For the 2012 tournament, the participating teams belonged to the provincial associations shown in Table 1. The teams belonging to the groups of Pichincha (Highlands) and Guayas (Coast) are considered to be the strongest teams in the championship. Most of the games between teams of Pichincha against teams of Guayas are considered classics in Ecuadorian football. These games have a long tradition of historic rivalry between their fans and usually have high coverage by the media, which raises attendance to the stadiums. The same phenomenon occurs with the games among teams in provincial associations with at least two teams like the associations of Pichincha, Guayas and Tungurahua, in the 2012 tournament. In terms of attractiveness, it is not desirable to play classic games in a specific set of tournament rounds, for instance, the first and the second round and the last two rounds. In the first rounds the fans may not be well motivated and in the last rounds a classic game could give an (unfair) advantage to the local team.

## 3. Integer programming formulation

Let $G=\{1,2,\ldots,7\}$ be the set of indexes for provincial groups. The set of teams of every provincial group is denoted by $G_g$, for all group index $g\in G$. For the 2012 Ecuadorian football tournament, according to Table 1, we have $|G_1|=4,|G_2|=2,\ldots,|G_7|=1$. We call matches between teams in sets $G_1$ and $G_2$ (also referred to as group 1 and group 2) *classic regional games* and matches involving teams in sets $G_g$, $g\in G$, with more than one team, *classic local games*. Moreover, let $I$ be the set of rounds, and let $I_F\subseteq I$ be the set of unattractive rounds in which classic regional games and classic local games cannot be scheduled.

A *playing pattern*, or just a *pattern*, is represented by the column vector $p^{(j)}=(p_{1j},p_{2j},\ldots,p_{ij},\ldots)^{\top}\in\{0,1\}^{|I|}$, indicating the sequence of matches at home venues ($p_{ij}=1$) or at away venues ($p_{ij}=0$). Two patterns are called *complementary* if the first has a match at home when the second pattern has a match away. Let $C$ be the set of *complementary patterns*. Note that, $|G_g|$ feasible patterns must be assigned to each group $g\in G$. Then, patterns matched on each round will determine the schedule of the tournament.

For any pattern, if there exists two consecutive home (or away) matches, one says that there is a *break*. The concept of break can be generalized by considering pairs of arbitrary rounds

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