

FROM O.R. TO THE WORLD CUP RUSSIA (WITH LOVE)

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THE SOUTH AMERICAN QUALIFYING TOURNAMENT for the 2018 FIFA World Cup has been arguably one of the tightest in recent history. In May 2017, with four out of 18 rounds remaining, there were eight teams with plausible possibilities to qualify for the final stage, to be held in Russia in 2018. While this can be mainly attributed to the even strength of the participating teams, Operational Research may have also contributed by means of a much more balanced schedule, in comparison to previous qualification tournaments.

BACKGROUND

The FIFA World Cup is both the most important football competition and the most followed sporting event in the world. Held every 4 years, the World Cup brings together national teams from FIFA's six continental confederations: AFC (Asia), CAF (Africa), CONCACAF (North





America, Central America and the Caribbean), CONMEBOL (South America), OFC (Oceania), and UEFA (Europe). The championship is played in two phases, the qualification and the finals. In the qualification phase, teams in each confederation compete to secure a place in the final phase. Only a limited number of teams advance per confederation. While about 200 national teams participate in the qualification phase, only 32 of them advance to the final phase. In the final phase, the 32 qualified teams fight for the world title in a series of matches taking place over a one-month period at venues usually located within a single host country. This tournament receives more international attention than any other single-sport event, attracting dozens of sponsors, intense world media coverage and hundreds of millions of viewers around the globe. In 2014, some 3.4 million spectators filled the stadiums for the World Cup finals matches in Brazil and the television coverage reached 3.2 billion people around the world.

With 10 South American teams vying for four places determined directly and a fifth determined by an intercontinental play-off, CONMEBOL is the confederation with the most places per competing

team. CONMEBOL holds nine titles out of the 20 World Cup tournaments played between 1930 and 2014, with Brazil having won five times and Argentina and Uruguay twice each. In April 2017, four of the South American teams – Brazil, Argentina, Chile, and Colombia – were among the top-5 teams of the worldwide FIFA Ranking.

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TRADITIONAL SCHEDULING

The South American qualification is a double round-robin tournament in which each team plays every other team twice over the course of 18 rounds, each of which consists of five matches. The entire tournament thus consists of 90 matches, and lasts about two years. The 18 rounds are scheduled in closely spaced pairs of match dates called *double rounds*. Matches on the first round of a double round are played over one or two days, and those in the following round are played four or five days later. In contrast, a double round can be separated by one or many

months from the preceding double round. One of the main reasons for the use of double rounds is to allow players in South American national squads, who typically play in top-tier European leagues, to play two qualifying matches on a single trip back to South America. This scheduling practice has been promoted by FIFA not only for CONMEBOL but for other confederations as well.

Between 1998 and 2014, the tournament was scheduled according to a so-called *mirrored scheme*, that is, in the first nine rounds each team played every other team once, while in the second nine rounds the matchups were repeated in the same order but with the home-away status reversed. Not only did this mirrored format last for many years, but also the schedule itself, which was identical for all four qualification tournaments leading to the World Cups between 2002 and 2014 (the only variation being that since Brazil was exempted from the process in 2014, the team that in each round would otherwise have played the Brazilians had a bye). During such a period, criticism over this schedule notoriously mounted over the years. While some of that criticism arose especially in countries with the frustration of not having qualified for a final tournament, some features were objectively unbalanced. For example, the so-called *breaks* (a sequence of two consecutive matches with the same home-away status) were unevenly distributed among the teams: for example, Bolivia had four of its nine away matches scheduled as two double round breaks, while Argentina and Brazil had no breaks at all. This unbalance was particularly controversial: consider that when an away break is scheduled within a double round, it forces a team to play two matches close together

without home advantage and possibly involving some long travel sequences. For example, one of Bolivia's double round breaks had it play away against Argentina in round 3 followed by an away game against Venezuela in round 4. This is the fifth longest of the side's 72 possible travel sequences (7,340 km, slightly more than the distance from London to Mumbai).

Away double-round breaks also imply that teams do not play at home for long periods. This is inconvenient not only for teams, but also for the local media and fans who might not get a chance to see their team for such a long period. For example, in the qualifiers for the 2010 World Cup, Uruguay did not play at home for more than 6 months (from September 2008 to March 2009) due to an away break in a double round. A similar situation affected Chile in the qualifiers for the 2014 World Cup, who did not play at home for almost a year, from November 2011 to September 2012.

Even when there are no breaks, the order in which the home-away games are spread within a double round matters for the teams. In general, teams prefer to start a double round with a home game, followed by an away game, rather than the other way around. This is for logistical reasons, as usually the players gather to train in their home country immediately preceding the first game of a double round, while after the second game they head back directly to their respective club teams. In this respect, the traditional schedule had an unbalanced distribution of home-away (H-A) and away-home (A-H) sequences in double rounds. For example, Argentina had nine H-A sequences while Chile and Venezuela had only one and, moreover, Brazil did not have any.

Despite these and other shortcomings, and although many



alternative schedule proposals were presented for the last four world cups, none of them received the support of a majority of CONMEBOL countries. Due to the lack of agreement and wide criticism, in January 2015, CONMEBOL decided that the schedule for the 2018 qualifiers would have to be defined by a random draw. A totally random schedule, however, is impractical. Thus, the ten countries were allowed to propose generic schedules that could serve as templates for the draw.

The O.R. approach allowed us to explore a variety of symmetric schemes, some completely new and some previously used in other football competitions, and to generate many candidate schedules that followed such schemes

O.R. SCHEDULING

In collaboration with the Chilean National Professional Football Association (ANFP), we have been applying Operational Research (O.R.) techniques to schedule football leagues

in Chile for the last 12 years. This collaboration has had great impact in the local professional leagues: it has translated into savings in travel costs and increased revenues for teams, it provides much more transparent and sense of fairness to all stakeholders (in comparison to previous traditional methodologies), and has helped improve various aspects of the competition such as, for example, avoiding clashes between fans of classic rivals in the same city, thus contributing to public order and better allocation of police resources. Our continued collaboration was recognized in being chosen as a finalist for the prestigious Franz Edelman award in 2016. In light of the positive experience of scheduling Chilean competitions, the ANFP decided to rely on O.R. techniques (and our group) for constructing a proposal schedule for CONMEBOL's qualifiers.

In our first approach to constructing a proposal, we tried to minimize the main disadvantages of the previous schedule, while keeping its mirrored scheme. However, using an integer programming approach, we quickly discovered that there is no mirrored schedule that can eliminate the number of breaks in double rounds (the least



draw of the qualifiers for the next World Cup took place in Saint Petersburg, in an event followed by TV all around the world. The draw of the South American qualifiers was conducted by Ronaldo and Forlán, former winners of the best player award at the FIFA World Cup 1998 and 2010, respectively. They drew balls from different pots. The balls in the pots contained the names of the teams and the numbers they would be allocated in the template schedule that we had generated by O.R.. They might not have understood the technicalities behind the schedule design, but the moment was undoubtedly a milestone in which operational research met football practitioners.

The resulting schedule greatly improved the balance of home-away sequences among all teams, which is perceived as scheduling fairness. First, every team plays exactly one home game and one away game in every double round. This means that the new schedule has no breaks within double rounds, while the traditional schedule had 18. Second, all teams have at least four and at most five H-A sequences in double rounds over the course of the tournament. This improves greatly over the imbalance of the traditional schedule, and it is the best achievable since the tournament has nine double rounds. In addition, the schedule resembles the symmetry of the mirrored scheme, by using a so-called *French scheme*. In this scheme, matches of the second half of the tournament follow the same order of the matches of the first half, with home-away status reversed (exactly as in a mirrored scheme), with the exception of the matches in the first round, which are scheduled (with the home-away status reversed) in the last round of the tournament. Another positive feature of the schedule is that

number that can be obtained while preserving the mirrored structure is 16). This result challenged us to find a solution that departed from the classical mirrored structure and that was acceptable in practice. The mirrored scheme was firmly established in the tradition of CONMEBOL, and we could foresee it was going to be hard to change it. The mirrored scheme is also easy to understand for the fans and the media. Our efforts then focused on trying to generate a schedule that could resemble the symmetry of the mirrored scheme, while improving its defects. The O.R. approach allowed us to explore a variety of symmetric schemes, some completely new and some previously used in other football competitions, and to generate many candidate schedules that followed such schemes. The approach was based on an integer programming formulation that captured the symmetric conditions together with other conditions specific to this tournament by means of constraints, and the desirable minimization of double round breaks as an objective function. The formulation was coded in a mathematical programming language and solved by

a commercial optimization solver. In the overall process, we tested several schemes and mix of conditions, which led us to find many candidate schedules that completely eliminated the breaks within double rounds. We presented these candidate schedules to ANFP's officials, who then chose one as the official proposal of Chile to CONMEBOL.

Transforming so many years of disagreement among CONMEBOL countries with respect to changing the schedule into a unanimous consensus is a significant achievement, which may probably not have been possible without the use of O.R.

RESULTS

Chile's schedule proposal was presented at a meeting of the ten countries' representatives of CONMEBOL, in May 2015. Although other countries also presented proposals, ours was unanimously selected. In July 2015, the

TABLE 1: FINAL STANDINGS OF THE SOUTH AMERICAN QUALIFIERS TO THE 2018 FIFA WORLD CUP

Place	Team	Played	W	D	L	F	A	Points
1	Brazil	18	12	5	1	41	11	41
2	Uruguay	18	9	4	5	32	20	31
3	Argentina	18	7	7	4	19	16	28
4	Colombia	18	7	6	5	21	19	27
5	Peru	18	7	5	6	27	26	26
6	Chile	18	8	2	8	26	27	26
7	Paraguay	18	7	3	8	19	25	24
8	Ecuador	18	6	2	10	26	29	20
9	Bolivia	18	4	2	12	16	38	14
10	Venezuela	18	2	6	10	19	35	12

it prevents any team from playing consecutive matches against Argentina and Brazil, unarguably the two strongest teams of South America. This has been traditionally considered a sport-fairness feature by CONMEBOL (the traditional schedule also had this feature). In the draw, this was handled by using a particular colour of balls for these two teams, so that they would be allocated to predefined placeholders that satisfied this condition in the template schedule.

In May 2017, with all teams having played seven home and seven away games, there was a very tough fight for qualification. In particular, the gap between the 4th and 5th teams, Uruguay and Argentina, was only one point. Up to the same round, in the qualifiers to all World Cups between 1998 and 2014, this difference ranged between two and five points. With four games remaining, 12 more points were still available to each team. As a result, even the 8th team in the standings, Peru, had a reasonable chance to qualify. This is in marked contrast to the 2002 and 2014 tournaments, where up to round 14 the eighth team was at 10 or 11 points of

difference with respect to the fourth, and comparable to the standings in the 1998, 2006 and 2010 qualifier tournaments.

While the facts above are for the most part caused by situations independent of the schedule, some small parts are arguably derived from having a more balanced O.R. scheduling approach. At any rate, it cannot be disputed that transforming so many years of disagreement among CONMEBOL countries with respect to changing the schedule into a unanimous consensus is a significant achievement, which may probably not have been possible without the use of O.R..

This work, together with numerous other contributions of sports scheduling, show that O.R. has great potential to support decision making in the practice of sports. Some competitions involve a large audience, the South American qualifiers are followed by about 400 million people, thus any improvement can convey a great social component. This also helps to promote O.R. and to introduce it in educational programmes, as we have experienced using sports scheduling topics at both university

and high school levels. Reporting new applications also helps to spread good practices; part of our research team has introduced the use of O.R. to schedule other sports competitions, such as the volleyball and the basketball professional leagues of Argentina. Currently, others related problems that drive our attention are producing a better FIFA ranking, referee assignment, and predicting match results.

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FOR FURTHER READING

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