

Buenos Aires, 20 de octubre de 2016



Sr. Decano de la Facultad de Ciencias Exactas y Naturales de la UBA

Dr. Juan Carlos Reboreda

Por medio de la presente le hago llegar a usted, y por su intermedio al Consejo Directivo de la Facultad, mi informe por el cuatrimestre sabático que me fuera concedido entre el 1 de febrero y el 31 de julio del presente año.

Durante esos meses tuve la oportunidad de viajar en varias oportunidades a Santiago de Chile, donde continué con los trabajos de colaboración con colegas de la Universidad de Chile, con quienes vengo desarrollando tareas conjuntas en temas de Investigación Operativa aplicada desde hace más de 10 años.

Una de las líneas de investigación es en temas de licitaciones combinatoriales, en conjunto con el Dr. Rafael Epstein, Profesor Asociado del Departamento de Ingeniería Industrial de la Facultad de Ciencias Físicas y Matemáticas de la Universidad de Chile. Como producto de esta actividad conjunta de investigación, se encuentra en prensa en *Annals of Operations Research* el siguiente artículo: Bonomo F., Catalán J., Durán G., Epstein R., Guajardo M., Jawtuschenko A. and Marenco J. "An Asymmetric Multi-Item Auction with Quantity Discounts Applied to Internet Service Procurement in Buenos Aires Public Schools".

Otra de las líneas de trabajo es en aplicaciones de Investigación Operativa a ciencias de la salud. En esta línea hemos dirigido en conjunto con Pablo Rey, investigador asociado al Departamento de Ingeniería Industrial de la Facultad de Ciencias Físicas y Matemáticas de la Universidad de Chile, la tesis del Magíster en Gestión de Operaciones de la Universidad de Chile de Patricio Wolff. Como producto de esta tesis hemos escrito el siguiente trabajo, también en prensa en *Annals of Operations Research*: Durán G., Rey P. and Wolff P., "Solving the Operating Room Scheduling Problem with Prioritized Lists of Patients".

Otro tema en el que hemos seguido colaborando con los colegas de la Universidad de Chile (en particular con el Dr. Andrés Weintraub) es en "sports scheduling". Como producto del trabajo en estos tópicos que hemos desarrollado desde 2005 a la fecha, nos presentamos al concurso Franz Edelman, organizado por la sociedad norteamericana de Investigación Operativa y Ciencias de la Gestión (INFORMS) y que premia a la mejor aplicación mundial de estos temas. Nuestro trabajo "Operations Research Transforms Scheduling of Chilean Soccer Leagues and South American World Cup Qualifiers", en coautoría de Alarcón F., Durán G., Guajardo M., Miranda J., Ramírez L., Ramírez M., Sauré D., Siebert M., Souyris S., Weintraub A., Wolf-Yadlin R. and Zamorano G., fue seleccionado como uno de los 6 finalistas de este concurso que es considerado el más importante a nivel mundial del área. La presentación de los 6 trabajos finalistas se hizo en el congreso anual de INFORMS realizado el pasado mes de abril en Orlando, USA, y allí concurrí como uno de los presentadores del trabajo.

Dentro de la misma área de “sports scheduling” en estos meses terminamos el trabajo “Scheduling the South American Qualifiers to the 2018 FIFA World Cup by Integer Programming”, en co-autoría con Mario Guajardo y Denis Sauré, éste último también profesor del Departamento de Ingeniería Industrial de la Facultad de Ciencias Físicas y Matemáticas de la Universidad de Chile. Este trabajo refleja la programación que hemos realizado para la Eliminatoria Sudamericana para el próximo Mundial de fútbol. El mismo fue presentado en la 28th European Conference on Operational Research, realizado en Poznan, Polonia, en julio pasado, y donde concurrimos con mi colega Mario Guajardo. El trabajo completo acaba de ser enviado recientemente para ser considerado para publicación en European Journal of Operations Research.

También en “sports scheduling” durante estos meses estuvimos trabajando con Pablo Rey, de la Universidad de Chile, y colegas y estudiantes de nuestra Facultad, en la escritura del trabajo “Mathematical Models for an NBA-type Scheduling Format in the Argentina’s National Basketball League”, en coautoría con Durán S., Marengo J., Mascialino F., and Rey P. Este trabajo es producto de la programación que venimos haciendo desde la temporada 2014-2015 para los torneos profesionales del básquet en la Argentina. Estamos en estos momentos en la etapa final de la redacción del manuscrito que será enviado a una revista internacional del área.

Otra línea de investigación en la que estuvimos trabajando en estos meses con Pablo Rey, de la Universidad de Chile, y otros colegas de diferentes centros académicos, tiene que ver con estudios analíticos aplicados a procesos electorales. Como producto de esta investigación estamos cerrando el trabajo “Efficient assignment of voters to polling places using analytics”, en coautoría con Giormenti M., Guajardo M., Rey P., Stier-Moses N., and Pinto P., que será enviado próximamente a publicación en una revista de Ciencias Políticas.

En lo que hace a formación de recursos humanos, el 18 de mayo pasado participé en la Universidad de Chile de la defensa de tesis del Magíster en Gestión de Operaciones de dicha Universidad, de mi tesista Javier Fuentes, bajo el título “Programación matemática para la confección conjunta de los fixtures de Primera A y Primera B del fútbol profesional chileno”. La misma fue aprobada y calificada con “sobresaliente”.

Dado lo expuesto, considero que he podido aprovechar muy bien estos meses de sabático para intensificar los trabajos de colaboración con colegas y estudiantes de la Universidad de Chile.

Sin otro particular, saludo a usted atentamente



Dr. Guillermo Durán
Profesor Asociado, dedicación exclusiva
Departamento de Matemática, FCEN-UBA

An asymmetric multi-item auction with quantity discounts applied to Internet service procurement in Buenos Aires public schools

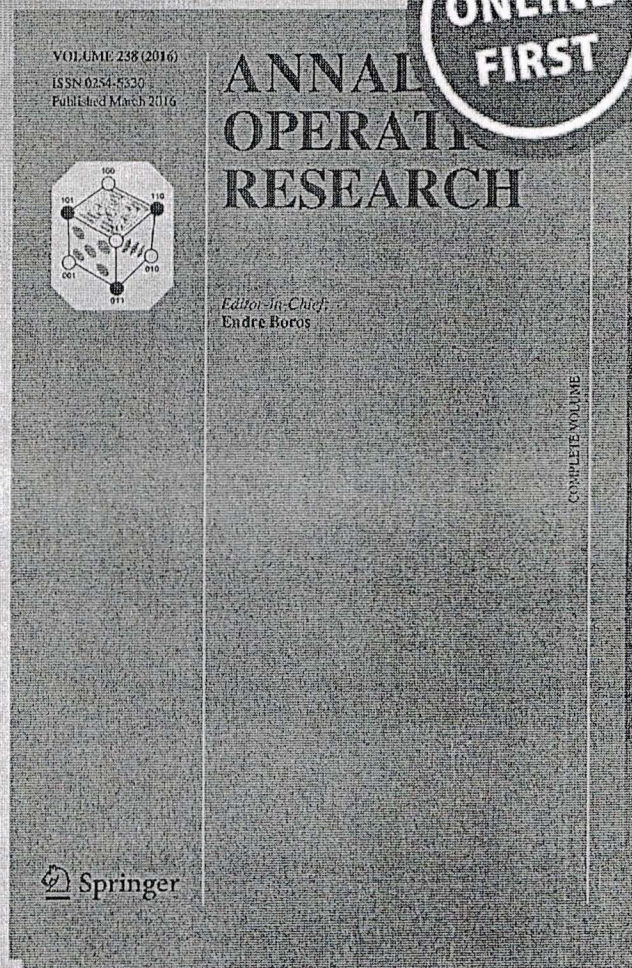
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An asymmetric multi-item auction with quantity discounts applied to Internet service procurement in Buenos Aires public schools

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Abstract This article studies a multi-item auction characterized by asymmetric bidders and quantity discounts. We report a practical application of this type of auction in the procurement of Internet services to the 709 public schools of Buenos Aires. The asymmetry in this application is due to firms' existing technology infrastructures, which affect their ability to provide the service in certain areas of the city. A single round first-price sealed-bid auction, it required each participating firm to bid a supply curve specifying a price on predetermined graduated quantity intervals and to identify the individual schools it would supply. The maximal intersections of the sets of schools each participant has bid on define regions we call competition units. A single unit price must be quoted for all schools supplied within the same quantity interval, so that firms cannot bid a high price where competition is weak and a lower one where it is strong. Quantity discounts are allowed so that the bids can reflect returns-to-scale of the suppliers and the auctioneer may benefit of awarding bundles of units instead of separate units. The winner determination problem in this auction poses a challenge to the auctioneer. We present an exponential formulation and a polynomial formulation for this problem, both based on integer linear programming. The polynomial formulation proves to find the optimal set of bids in a matter of seconds. Results of the real-world implementation are reported.

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Abstract

The scheduling of surgical interventions directly impacts the number of patients that can be treated with given operating room resources. Medical centres often do not respond satisfactorily to the demand for interventions, and the shortcomings of traditional manual scheduling approaches contribute to the growth of waiting lists. In addition to the timetabling aspect, operating room scheduling methods must determine the order in which patients should be treated as a function of their relative priorities. This paper develops and compares two optimization models and two algorithms for scheduling interventions over a defined period that satisfy patient priority criteria. The four mathematical methods were studied under a range of different scenarios using real data from a public hospital in Chile. Improvements in operating room utilization rates using the proposed formulations ranged from 10 to 15 % over the current manual techniques, but the choice of method in any given real application will depend on the scenarios likely to be encountered.

Keywords (separated by '-') Operating room - Integer programming - Exhaustive enumeration - Patient priority

Footnote Information

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Solving the operating room scheduling problem with prioritized lists of patients

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Operations Research Transforms the Scheduling of Chilean Soccer Leagues and South American World Cup Qualifiers

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For the past 12 years, the Chilean Professional Soccer Association (ANFP) has applied operations research (OR) techniques to schedule soccer leagues in Chile. Using integer programming-based methods, the ANFP decides which matches are played in each round, taking into account various objectives, such as holding down costs and ensuring engaging tournaments for the fans. It has scheduled more than 50 tournaments using this approach, resulting in an estimated direct economic impact of about \$59 million, including reductions in television broadcaster operating costs, growth in soccer pay-television subscriptions, increased ticket revenue, and lower travel costs for the teams. This application of OR has also had significant noneconomic impacts. First, the incorporation of team requirements and various sporting criteria has improved process transparency and schedule fairness, increasing fans' interest in local professional tournaments; second, because of the high portability of these techniques, they have been used successfully to schedule sports leagues in other countries; examples include volleyball and basketball in Argentina, and the South American qualifiers for the 2018 Soccer World Cup. Furthermore, the models and methods used in this scheduling application have been disseminated widely, helping to promote OR as an effective tool for addressing practical problems. Our outreach activities have reached thousands of high school and university students in four countries and a more general audience of millions of television viewers and Internet users.

Keywords: sports analytics; scheduling; integer programming; soccer.

Association football, also known as football or soccer, is the most popular sport in the world. Although the sport's popularity might vary from region to region, it undoubtedly attracts worldwide attention. Practiced by approximately 200 million registered players, soccer is a central aspect of the cultural identity of many countries, over 200 of which compete to qualify for the World Cup every four years. A report in Deloitte (2016) revealed that the world's top 10 money league teams have over 600 million social media followers worldwide (including Facebook, Twitter, and Instagram). In economic terms, this report estimated their combined revenue during 2015 at \$5 billion. This figure is comparable to the revenue generated by the 2014 World Cup.

Soccer is by far the most popular sport in Chile, where it has been played professionally since 1933. The Chilean Professional Soccer Association (ANFP) organizes the professional

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Order of Authors: Mario Guajardo, PhD; Guillermo Durán, Professor; Denis Sauré, PhD

Abstract: Every four years, the 10 national teams members of the South American Football Confederation (CONMEBOL) compete for one of the slots available to South America in the final phase of the FIFA World Cup. The qualifying phase consists of a double round robin tournament, played in 9 match-days, with every team playing twice on each match-day. The overall tournament is spread throughout 2 years, so match-days are months apart from each other. After using a same mirrored schedule for about twenty years, and persistent complaints from its members, CONMEBOL decided to change the schedule for the 2018 World Cup. Supported by one of CONMEBOL's members, we used integer programming to construct schedules that overcome the main drawbacks of the previous approach. After exploring many design criteria, we proposed a candidate schedule based on a French scheme. The main feature of the proposed schedule is that every team plays once at home and once away on each match-day, stepping away from traditional symmetric (mirrored) schemes. This proposal was unanimously approved by CONMEBOL members and is currently being used in the qualifier tournament to the 2018 FIFA World Cup Russia.

Scheduling the South American Qualifiers to the 2018 FIFA World Cup by Integer Programming

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October 7, 2016

Abstract

Every four years, the 10 national teams members of the South American Football Confederation (CONMEBOL) compete for one of the slots available to South America in the final phase of the FIFA World Cup. The qualifying phase consists of a double round robin tournament, played in 9 match-days, with every team playing twice on each match-day. The overall tournament is spread throughout 2 years, so match-days are months apart from each other. After using a same mirrored schedule for about twenty years, and persistent complaints from its members, CONMEBOL decided to change the schedule for the 2018 World Cup. Supported by one of CONMEBOL's members, we used integer programming to construct schedules that overcome the main drawbacks of the previous approach. After exploring many design criteria, we proposed a candidate schedule based on a *French scheme*. The main feature of the proposed schedule is that every team plays once at home and once away on each match-day, stepping away from traditional symmetric (mirrored) schemes. This proposal was unanimously approved by CONMEBOL members and is currently being used in the qualifier tournament to the 2018 FIFA World Cup Russia.

Keywords: OR in sports; OR in practice; Sports scheduling; Integer programming; Football.

- Integer programming produces schedule of FIFA World Cup South American Qualifiers
- A mirrored schedule without double round breaks is infeasible
- New schedule reduces double round breaks from 18 to zero compared to old schedule
- New schedule unanimously approved by the ten South American countries
- New schedule currently being used for the qualifiers to 2018 FIFA World Cup Russia

Efficient assignment of voters to polling places using integer programming and queuing theory

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August 11, 2016

Abstract

Research on political representation has traditionally focused on the design of electoral systems. Yet, there is ample evidence that distance to polling stations and waiting in line to vote result in lower turnout and undermine voters' confidence in the electoral system. Authorities in charge of administering elections can selectively choose to vary the costs of political participation for different individuals and groups, leading to biased electoral outcomes. Quantifying the costs of voting and designing fair, transparent and efficient rules for voter assignment are important tasks for theoretical and practical reasons. We rely on linear programming to develop a model aimed at minimizing the travel and wait time experienced by voters. Based on insights from queuing theory we use this model as a benchmark to quantify the extra participation costs faced by voters in Argentina. To estimate the parameters needed by the models, we draw on real world data on the 2013 midterm elections in the city of Buenos Aires. We show that the voter assignments produced by our model would cut the average voting time by more than 27%, underscoring the inefficiencies of the current method of voter assignment. Our modeling strategy and findings help generate better estimates of the role of geographical and temporal conditions on voter turnout and electoral outcomes.

Keywords: Elections, Voting Costs, Assignment Problem, Linear Programming, Queuing Theory, Geocoding

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Ciudad de Buenos Aires, **19 DIC 2016**

VISTO lo dispuesto en el artículo 50° del Estatuto Universitario que instituye el Año Sabático para profesores regulares de la Universidad,

CONSIDERANDO:

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Que es necesario cumplir con lo establecido por los Art. 13° y 14° de la citada resolución,

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