IFORS NEWS

International Federation of Operational Research Societies

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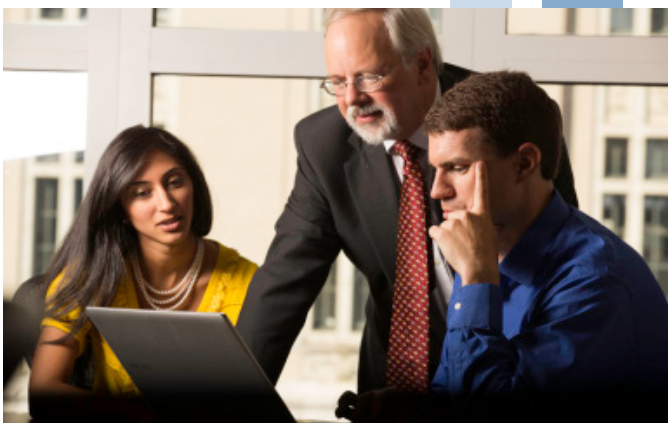
What's Inside

From the President

In Praise of Volunteers

Mike Trick <trick@cmu.edu>



I first became a volunteer in operations research in the mid 1990s when I became what might be called an "independent volunteer": I began to collect webpage links being generated on the nascent internet, organizing them into "Michael Trick's Operations Research Page". This led directly to my working with the then-new society INFORMS (the merger of two US-based societies) to create, with the help of a group of dedicated volunteers, their web page. Eventually, this led to my becoming President of INFORMS, Vice-President of IFORS, and now President of IFORS, all volunteer positions. And it led to a lot more volunteer opportunities: as a conference chair, competition judge, funding evaluator, and much more.

In the 50 national societies comprising IFORS, there are no more than 30 paid positions, almost all of them in the large societies of INFORMS and The Operational Research Society (United Kingdom). IFORS itself has one part-time paid position, that of Secretary. All the other work done by these societies is carried out by volunteers. We rely on the efforts of volunteers to organize conferences, produce newsletters, advertise the field, educate the public and all the other things societies and individuals do on behalf of our field. It is their enthusiasm and dedication that advances our field.

All societies I have talked to have a strong need for more volunteers. There is a need for people who love and understand operational research to step forward and take on existing activities and to create new ones. At IFORS, we rely on volunteers for committees, journals, conferences, and publications. Without the volunteers of IFORS, nothing gets done.

I personally have found volunteering, both on my own and through organizations, extremely rewarding. I have met wonderful people and I have a sense of accomplishment through what we, as a group, have created. I hope that others (you!) will also look for opportunities to volunteer at an operational research organization, perhaps your national society.

I would like to highlight one volunteer in particular who has had a tremendous impact on IFORS. Elise del Rosario has worked tirelessly in a number of roles for IFORS, including President, Past President, Vice President, Chair of the Developing Countries Committee, organizer of ICORD conferences as member of the developing countries committee, and, Chair of our Website and Newsletter Committee. In particular, it is due to Elise that we have the excellent IFORS News you are now reading. She created the newsletter and has been the driving force behind it. Without Elise, IFORS would not be anywhere near the organization it is today.

But no activity is forever, and Elise is moving on to other endeavors, making this the last IFORS News she will edit. I can only hope that more volunteers will follow her example and will continue to advance the field of operational research and IFORS. Thanks Elise!

From the Editor

Thank You All!

Elise del Rosario <elise.del.rosario@stepforward.ph>

This column is traditionally about what is contained in this particular issue of the IFORS News – more descriptions than one would find in the Table of Contents, as well as the theme that runs through the issue. This time around, however, allow me to deviate a bit and express my gratitude to you all.

You would have read our President's note about my leaving all IFORS responsibilities, owing to demands of other commitments that I have accepted. I may be leaving my work here, but I am definitely leaving my heart here too. IFORS had been the organization that had taught me a lot of things, foremost of which is that people care.

When I was given the responsibility by then President Peter Bell to head the Developing Countries Committee in 1992, I felt like joining a welcoming family. After this, I had the opportunity to work with Andres Weintraub, again as DC Committee head and then as IFORS Vice President to Paolo Toth. These three past Presidents of IFORS mentored me – they had different styles which were unique but equally effective in leading the organization. I must say I have learned a lot from all of them.

I then became President and it was with the full support of the AC and Mary Magrogan that we were able to push the IFORS agenda forward. A focus on the members became my priority and I received great help from our webmaster, Ruel Tan in helping set up a new website. I was lucky enough to convince Hans Ittmann to accept my offer to come up with and edit the IFORS newsletter. Both of them are still working for the IFORS News, Ruel as layout artist and Hans, the regular book reviewer.

The Presidents who came after me, Dominique de Werra and Nelson Maculan, were both a joy to work for. While they had different operating and decision-making styles, optimal decisions were always arrived at for the good of IFORS.

In the process of working for IFORS, I developed hundreds of friends who I would never have had the pleasure of knowing if not for our international organization. Let me mention a few who have made such a positive impact on me – Helle Welling, Grazia Speranza, Elena Fernandez, Sue Merchant, Karla Hoffman, Luciana Buriol, Sarah Fores, Graham Rand, John Ranyard, Jonathan Rosenhead, Tatsuo Oyama, and the ever-pleasant and ever-ready-to-help Willi Weber. He would always come back with news about conferences he attends! Of course, a million thanks to the IFORS correspondents who have made my life easier by sending in the news. I have not met you all in person, but I have memorized your email addresses by heart!

Of course, there is our current President Mike Trick. He has impressed me with his seemingly boundless capacity for work and his capability in getting things done. Clearly, Mike is a blessing to IFORS. And so, it is with confidence that I withdraw from IFORS knowing that it will continue innovating to be of service to the international OR community. Of course, leaving IFORS doesn't mean cutting ties completely. I may attend some of the IFORS, EURO or ALIO conferences if time and interest permit – so our paths may continue to cross again in the near future.

Again, a big thank you to the international OR community, for making my 25 years in IFORS such a wonderful, rewarding, and memory-laden adventure!

Indonesia GROUP: The organizing committee poses with G. W. Weber and H. Mawengkang (5th and 6th from left, respectively)

Growing Local OR through International Collaboration

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The 4th International Conference on Operational Research 2017 (InteriOR 2017) was held from August 21 to 23 at the Grand Aston City Hall Hotel, Medan, Sumatra, Indonesia. It was a collaborative effort between the Department of Mathematics, Universitas Sumatera Utara, Medan, Indonesia, and the Indonesian Mathematical Society (IndoMS), Section Aceh and North Sumatra Province. A biannual conference, the series started in 2011. Conference topics had four sections: Pure Mathematics, Applied Mathematics, Operational Research, and Statistics.

The keynote talks were focused especially on the advanced achievement on Operational Research and their Applications. The conference theme on ***Better Living with Operational Research*** was discussed by the four keynote speakers for the conference: Gerhard Wilhelm Weber, Institute of Applied Mathematics, Middle East Technical University, Turkey, on *Regional Atmospheric Correction by Conic Multivariate Adaptive Regression Splines*; Abdel Salhi, Department of Mathematical Sciences, Colchester, Essex University, UK, on *New Developments in the Plant Propagation Algorithm: A Review*;Yong Hong Wu, Department of Mathematics and Statistics, Curtin University, Perth, Australia on *Application of Partial Differential Equations in Industrial Modelling and Optimization*; and Saib Suwilo, Department of Mathematics, Universitas Sumatera Utara, Medan, Indonesia on *Competition Index Of Primitive Two-Colored Digraphs*.

InteriOR 2017 was attended by 300 participants, with more than 140 abstracts accepted for presentation. The organizers were models of hospitality and generosity as they led the participants in a visit to the world-famous and spectacular *Lake Toba* (Sumatra). *InteriOR 2017* was associated with two conferences, namely the *1st IconICT (The International Conference on Information and Communication Technologies)* in HARAPAN, Medan, Indonesia, August 2017 (http://iconict-stth.com), and an International Public Lecture at Tunas Bangsa Computer Management Academy, Siantar, Sumatra, Indonesia.

Having attended all four InteriOR conferences, G.W. Weber observed the strong growth shown by the OR community in Indonesia. He recognized the great role of the participants from Indonesia during EURO conferences and cited the important role of H. Mawengkang without whom the InteriOR Conference Series would not have been possible.

GOR Conference Tackles Analytics and the Digital Economy

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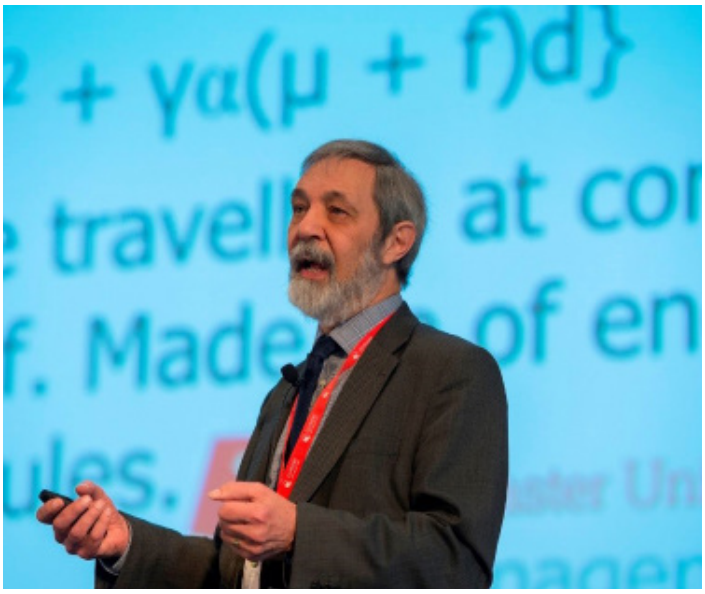

R. Eglese gives his plenary talk

The annual International Conference on Operations Research (www.or2017.de) of the German OR Society (GOR), hosted by Freie Universität Berlin, Germany, was held from September 6 to 8. The 900 delegates who participated in the conference were able to choose from 26 parallel streams featuring around 600 contributed presentations. In addition, five pre-conference workshops were offered and enjoyed good attendance: Hands-on: Optano Modeling, Hackathon: Gurobi-TomTom OR 2017 Challenge, IBM Analytics – Decision Optimization, GAMS, Solving with SATALIA – Our Solve Engine and the Business of Academia. Similarly appreciated were the two plenary talks given by two leading researchers: Richard Eglese, Lancaster University, United Kingdom who talked on *Green Logistics: Decision Analytics for Sustainable Transportation;* and Andrea Lodi ,École Polytechnique de Montréal, Canada, on *Big Data, Optimization And Learning.*

During the opening ceremony, the scientific prize of the GOR for excellent contributions in the area of Operations Research was presented to Erwin Pesch of the University of Siegen. The GOR Dissertation Prize was given to four PhD. theses as follows: Pirmin Fontaine of TU München, Betreuer on *Methodological Advances and New Formulations for Bilevel Network Design Problems*; Igor Kozeletskyi of Universität Duisburg-Essen on *Game-Theoretic Approaches to Allocation Problems in Cooperative Routing*; and Kevin Schewior of TU Berlin on *Handling Critical Tasks Online – Deadline Scheduling and Convex Body Chasing*; and Marlin Wolf Ulmer of TU Braunschweig on *Anticipation in Dynamic Vehicle Routing*.

Erwin Pesch Receives GOR Award for scientific excellence. Prize winners all smiles as they hold on to their bouquets.

Also the three following MSc. theses were selected for the GOR MSc. prize: Felix Happach of TU München: *Stable Clusterings and the Cones of Outer Normals*; Adam Schienle of FU Berlin on *Shortest Paths on Airway Networks*; and Markus Seizinger of Universität Augsburg on *The two dimensional bin packing problem with side constraints*.

During the conference, eleven semi-plenary talks were delivered by Martin Bichler of TU München on *Market Design: A Linear Programming Approach*; Marco Lübbecke of RWTH Aachen on *Optimization Meets Machine Learning*; Christian Mattfeld of TU Braunschweig on *Models And Optimization In Shared Mobility System*; Alexander Martin of FAU Erlangen-

Nürnberg on *Network Flow Problems with Physical Transport*; Meinolf Sellmann of General Electric, US, on *Meta-Algorithms*; Arne Strauss of University of Warwick, UK, on *Last Mile Logistics*; Hans-Georg Zimmermann of Siemens AG on *Data Analytics, Machine Intelligence and Digitalization at Siemens*; Sven Crone of Lancaster University, UK on *The Rise of Artificial Intelligence in Forecasting- Hype vs. Realworld Success Stories*; Christoph Klingenberg of Deutsche Bahn on *Improving On-Time Performance at Deutsche Bahn*; Anna Nagurney of University Of Massachusetts, US on *Blood Supply Chains: Challenges For The Industry And How Operations Research Can Help*; and Dorothea Wagner of KIT on *Route Planning in Transportation – New Results and Challenges*.

The rich scientific program was matched by the well-thought out social program which included three evening events: a get-together held at the Henry-Ford Building on Tuesday offering an amazing barbecue with two colorful cocktails; a Welcome Reception at the Wasserwerk Berlin-Wilmersdorf on Wednesday; and the conference dinner at the Seminaris Campus Hotel Berlin-Dahlem, featuring a great band and good food. During all these events, a lot of ideas were exchanged, and friends made.

Participants of the pre-conference Workshop ready and willing to apply lessons learned.

Thanks are due to the organizing and program committees as well as the students who provided the much-valued assistance to the delegates and the organizers. Participants welcomed the next GOR conference announcement which is going to be co-organized with the Belgian Operational Research Society(ORBEL) in Brussels, Belgium, from September 12 – 14, 2018, at the MCE Conference & Business Centre. Abstract submission deadline is April 30, 2018.

Announcements about the next EURO conferences, in Valencia, Spain (2018; http://euro2018valencia.com/) and Dublin (2019; https://www.euro2019dublin.com/), were presented during the closing session by Bernard Fortz and Gerhard Wilhelm Weber, respectively.

Deepening OR Connections with Experimental Science and Engineering

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The 4th International Conference on Computational and Experimental Science and Engineering" (ICCESEN 2017) was successfully held in Kemer, Antalya, Turkey, from October 4 to 8, 2017 (http://2017.iccesen.org/). The conference was organized by the various universities in Turkey under the leadership of. Iskender Akkurt from Süleyman Demirel University, Isparta.

The conference hosted around 600 registered participants from around 50 countries. Scientists and engineers presented about 1000 papers in the areas of mathematics, industrial engineering, physical science and technology, computer science, business/economics, education, medicine and related fields. Oral and poster presentations on different topics were organized in 10 themes and sessions. In its fourth year, *ICCESEN 2017* has proven to be a remarkable international platform for sharing researches, exchanging ideas, advancing knowledge and insights on a wide range of subjects.

Invited Speakers were: Madjid Fathi (Department of EECS, University of Siegen, Germany) who spoke on *Big Data Analysis and their Approach for Smart-City Development*; Oleg Burdakov (Linköping University, Department of Mathematics, Linköping, Sweden): *A Reduction of Cardinality to Comlementarity in Sparse Optimization*; Gerhard-Wilhelm Weber (Poznan University of Technology, Faculty of Management Engineering, Poland; METU, Ankara, Turkey) on Minimal Truncation *Error Constants for Runge-Kutta Method for Stochas tic Optimal Control Problems*; Ali Poyraz

Co-author Burcu presents her paper.

Gürson (Kocaeli University, Kocaeli, Turkey) on Brand-Marka; A. Beril Tuğrul (Istanbul Technical University, Istanbul, Turkey): *Radiotracer Applications for Determination of Flow Parameters*; Alexandre A. Bachkirov (Sultan Qaboos University, Oman) on *Creation of Global Management Knowledge: Challenges for non-Western Scholars*; H. Şükür Kılıç (Selçuk University, Konya-Turkey) on Laser Technologies for the Mankind; Hamid Reza Irani (University of Tehran, Faculty of Managament and Accounting, Qom, Iran) on *What is the Best Place for Publishing Our Article?*; Kalim Siddiqui (University of Huddersfield, England, UK) on *Global Convergence and the Issue Catching Up- Changing Economies of the Developing Countries*; and El-Sayed El-Aswad (United Arab Emirates University, UAE) on *Well-Being in the Arab World: An Anthropological Perspective*.

The good number of presentations and distinguished array of speakers was complemented by the friendly environment of the congress and the natural beauty of Kemer, which made the conference very memorable. Kemer is on the Gulf of Antalya with 53 km of seacoast with the impressive ridges of the western Taurus Mountains in the background. The coast has the typical Mediterranean, hot, dry weather and warm sea. Kemer and coastal villages in the province play a very important part in the tourism of Turkey.

The congress provided a venue for a discussion of the connections among the different branches of science, engineering and Operational Research. The interdisciplinary works were explained to show the interactions of OR with biology, economy, engineering, medicine and social sciences. The congress also enabled a discussion of past accomplishments and plans for 2018 and beyond. Participants were invited to the forthcoming OR events, namely *EURO 2018* in Valencia (http://euro2018valencia.com/), and *EURO 2019* in Dublin (https://www.euro2019dublin.com/).

Audience listens attentively to the speaker

VI SMIO Conference:

Agreement Sealed; Conference Delivered

Ángela Esquer Urtusuástegui <angela.esquer@up.edu.mx>

Graced by leading speakers in the field of operations research from different parts of the world, the VI Conference of the Mexican Society of Operations Research (SMIO) was held from October 4 to 6 at the Universidad Panamericana (UP) Guadalajara Campus in Zapopan, Jalisco, Mexico.

Leading OR personalities included: Susana Gómez of UNAM, Mexico; José Ventura of Pennsylvania State University, USA; Emilio Carrizosa from University of Seville, Spain; and Mauricio Resende from Amazon, USA. The parallel sessions allowed everyone to exchange ideas and share progress in their respective fields even as they established contacts for joint research and / or collaboration.

Juan Antonio Díaz, Vice President of the SMIO opened the conference together with Abraham Mendoza Andrade, Institutional Research Director of the UP System, Juan de la Borbolla, Rector General of Campus Guadalajara, Elías Olivares Benítez, President of the Organizing Committee and José Luis González Velarde, President of the Scientific Committee.

The first day plenary talk by Gómez entitled *Complex Applications of Global Optimization for Industry and the Environment* was followed by parallel sessions on supply chain design, production systems, OR applications and multi-criteria applications. The afternoon sessions centered around energy, packing and territorial design. The first day concluded with a plenary talk *Infrastructure Development for Alternative Fuel Vehicles in Transportation Networks* presented by Ventura. This was followed with cocktails sponsored by Bodegas de Santo Tomás.

The second day featured the plenary talk by Carrizosa on *Mathematical Optimization in Data Science*. As in the first day, parallel sessions on natural disasters and humanitarian aid, routing, and health followed. In the afternoon, Resende presented the plenary talk *Some Recent Advances in Greedy Randomized Adaptive Search Procedures*. Parallel sessions on production planning and control, transportation, agricultural and business applications were held. The annual meeting of the society was then presided over by President David Muñoz who reported on activities carried out during the year. David Romero was elected Vice President for the next two years. The city of Saltillo was designated as the venue for the 2018 SMIO Conference, and Instituto Tecnologico Autonomo de Mexico (ITAM) for the 2019 Conference. At the end of the meeting, Emilio Carrizosa and David Muñoz SEIO (Spanish OR Society) and SMIO Presidents, respectively, signed an agreement of collaboration between the two societies.

The evening featured the gala dinner which gave everyone the opportunity to exchange ideas and establish collaboration with other researchers from different universities. Parallel sessions on the third day were on location, production programming, statistical methods, inventory routing and more OR applications.

Participants expressed satisfaction with the quality of the exchange and eagerness to participate in future events of the Mexican Society of Operations Research.

Participants pose for a group picture

SYSORM: Preparing the OR Leaders of Tomorrow

F. Javier Martin Campo <javier.martin.campo@mat.ucm.es>

The First Spanish Young Statisticians and Operational Researchers Meeting (SYSORM) -https://congresos.ugr.es/sysorm17/ -took place in the lovely city of Granada, Spain from November 13 to 15. Organized for and by young researchers, the meeting sought to provide a nurturing environment for newer generations of talented researchers in Statistics and Operations Research. PhD students and young PhDs comprised the 41 participants coming from Spain, Portugal, and France. A common session for all (i.e., no parallel or breakout sessions) ensured that everyone had a common bonding and learning experience.

Four renowned international researchers took part as plenary speakers: Pierre Bonami (IBM), Juan Antonio Cuesta-Albertos (University of Cantabria), Ingrid Van Keilegom (University of Leuven), and Rafael Martí (University of Valencia). Their talks raised awareness of new challenges in Statistics and Operations Research with the intent of encouraging participants to explore those areas.

The meeting was held under the auspices of the Spanish Society of Statistics and Operations Research (SEIO, Spanish acronym) with financial support from SEIO, EURO, and the University of Granada. Facilities for the meeting were provided by the Institute of Mathematics of the University of Granada (IE-math-GR). The Portuguese and French societies, APDIO and ROADEF, supported their respective delegates.

Very familiar with what an excellent program should look like, the last four winners of the "Ramiro Melendreras" SEIO award comprised the Meeting Chairs as follows: F. Javier Martín-Campo (Complutense University of Madrid), Carmen Aguilera-Morillo (Carlos III University of Madrid, UC3M), Eduardo García-Portugués (UC3M), and Beatriz Sinova (University of Oviedo). This SEIO award recognizes the work of young researchers in Statistics and Operations Research. The meeting was a huge success, owing to the enthusiastic work of the Organizing Committee chaired by Víctor Blanco and Javier Álvarez Liébana, together with F.J. Esquivel, D. Miranda, B. Cobo, S.M. Valenzuela, D. Molina, and J.L. Romero.

The tireless work of the Scientific and Organizing Committee members, together with the eagerness of all the participants, combined with the friendly and warm atmosphere bodes well for new future projects – in fact, the forthcoming 2nd SYSORM in 2019, among others, is already in the pipeline!

UNIVERSIDAD DE GRANADA

IEMATH-GR Instituto de Matemáticas de la Universidad de Granada

SEIO

EURO The Association of European Operational Research Societies

Conference Looks Back at the Last 30 Years of OR in the Philippines

Iris Ann Martinez <igmartinez@up.edu.ph>

Moderator Bing del Rosario (left) directs the discussion of the Past Presidents Panel consisting of (l to r): Elise del Rosario, Aura Matias, Noli Macalalag, JC Mercado and Alleli Domingo.

Founded in 1987, the Operations Research Society of the Philippines celebrated its 30th year anniversary during its national conference on November 24 at the Richmonde Hotel in the capital city of Metro Manila. Lively plenary sessions marked the event, with past presidents of the Society taking key plenary spots.

Two tutorials were handled by Vicente Reventar on the topic *System Dynamics and the Integrated Sustainable Development Goals (iSDG) Planning Simulation Model* and another one by Francis Miranda on *Methodology to Estimate Online Sales Using Automated Web Crawling, Predictive Analytics and Statistical Extrapolation*. Meanwhile, a one-hour "talk show" format was conducted during the Plenary Panel with Past Presidents. Fielding the questions was moderator Jaime (Bing) del Rosario.

This talk show session was able to solicit the five presidents' perspectives on a wide range of issues, including breakthroughs and ORSP accomplishments and personal experiences in trying to get OR to work. All the presidents were unanimous in agreeing that their OR experience enabled them to adopt a system view of problems, structure and define them before embarking on a solution, whether for a client or in their personal lives. The topic of OR in the Philippines and how it compares to OR practice in other countries yielded a general view that OR practice is lagging, nationally compared with other APORS countries such as Australia. The topic of whether incorporating "Analytics" into the OR name yielded a divided outcome, with some preferring to retain the OR name and others, ready to embrace Analytics.

The keynote given by Department of Science and Technology Secretary Fortunato de la Peña on *The Role of Science & Technology in Environmental Sustainability* discussed the ways in which OR could be used to address sustainability issues in accordance with the 2030 UN Global Goals for Sustainable Development. Himself an OR person, the Secretary discussed various optimization projects in the S&T sector.

In her talk on *Engineering a Sustainable Future through Process Systems Engineering*, Kathleen Aviso discussed her extensive work in the development of mathematical models to aid in decision-making for the design of resource conservation networks, identification of energy efficient supply chains, selection of sustainable supply chain pathways and disaster risk analysis and management. On the other hand in his talk on *Proposing an Operations Research Toolbox to Resolve Problematic Situation in Energy and the Environment*, Michael Promentilla illustrated the use of a problem structuring method on a case involving industrial parks (EIPs) which are being promoted as a promising strategy to achieve sustainability in a circular economy.

The parallel sessions tackled various topics around environment, climate, risk, supply chains, manufacturing and traffic issues. The close to 200 participants gathered back for the Closing Plenary which tackled a common concern of all OR people, namely, *How to Present Data and/or Analytics Results That is Easily Understandable by Any Audience* delivered by Wilson Gan. This was quickly followed by a business meeting and fellowship. A relief to the organizers, participants generally found the conference excellent.

Promoting Health and Wellness through OR

Andres L. Medaglia < andres.medaglia@uniandes.edu.co>

The project described here was awarded the IFORS Prize for OR in Development, a paper competition held in conjunction with the IFORS Triennial. It was awarded in Quebec City in July 2017. Co-authors of the project paper were: Abolghasem, S., Solano, F., Bedoya, C. D., Navas, L.P., Ríos. A. P., Pinzón. E. A., Medaglia, A. L., Sarmiento, O. L. (*) Parts of this article were adapted from the working paper by Abolghasem et al. (2017).

Milena Corredor, an active housewife aged 57, leaves her home at 5:50 am on her bike to meet her friends in a nearby park in Bogotá (Colombia). When she arrives, everything is in place for an active session of rumba in open space, mostly attended by women and managed by trained instructors. Milena is one of the regular participants of the Recreovía program in Bogotá. She emphatically claims that she plans to attend the program "with passion [...] until she dies".

What is special about the Recreovía programme? In Bogotá, a city with about 8 million people, the programme provides free physical activity classes such as rumba, pilates, folk dance, aerobics, stretching, and martial arts in parks, plazas, streets, shopping and community centres led by trained instructors. The Recreovía programme was inaugurated in 1995 and is coordinated by the District Institute of Sports and Recreation of Bogotá (IDRD). In 2015, the Recreovía programme offered physical activity classes in 41 hubs located in low to middle-income neighbourhoods within 95% of the localities (administrative geographic subdivisions) of Bogotá. Classes are offered seven days/week for two hours on weekdays and three to five hours on Sundays and holidays. It was estimated that nearly 641,956 people participated in 2015, a significant attendance relative to Bogotá's population.

In an era where people's health has been unjustly impacted by their income, age, gender, education, ethnicity, and socio-economic status, the Recreovía programme serves the entire community with an inclusive health-focused approach. Accordingly, the necessity of bringing healthy living into people's daily lives has been and will continue to be a significant challenge for public health practitioners and officials of the IDRD. This challenge involves assigning resources innovatively and efficiently to identify suitable locations for expanding the programme and implementing new Recreovía hubs throughout the city.

Armed with a decade of work experience at IDRD and a knowledge of OR, the Universidad de los Andes Epidemiology Group Director Olga L. Sarmiento put

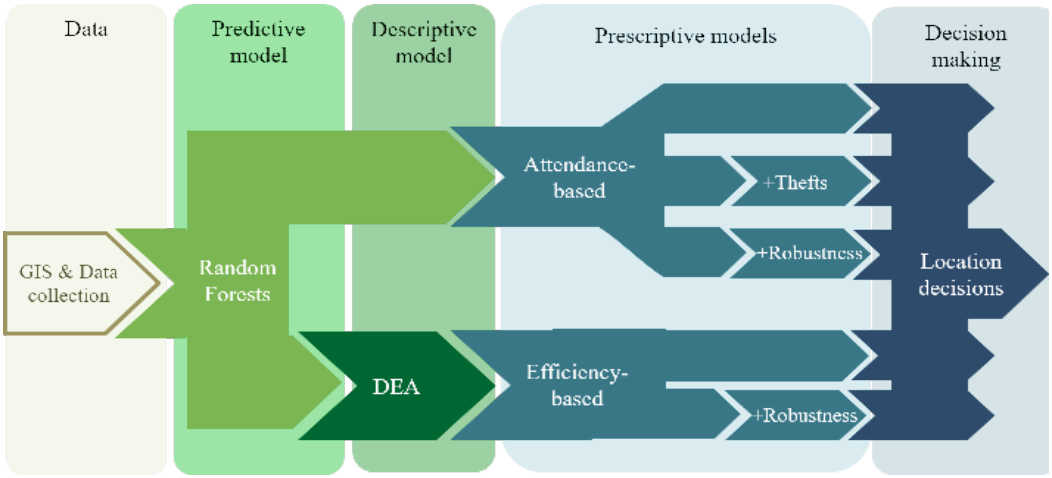

Figure 1. Five components of the methodology.

together a multidisciplinary team composed of physicians, public health experts, physical education experts, software engineers, and operations researchers. Together, members of the team produced RecreoBOG, a decision support system (DSS) that helps IDRD select the best hubs for the Recreovía program expansion in Bogotá.

The team worked on a methodology for locating Recreovía hubs with five interweaved components (see Fig. 1). The first component relates to data collection: information from each park comes from a geographical information system (GIS) and experts from the IDRD (e.g., geographical location, park area, schedules, theft records, and historical attendance at existing hubs, among others). The second component is a predictive model based on random forests (James et al., 2013) which estimates the attendance at potential Recreovía hubs depending on the area of the park and its schedule, among other characteristics.

> "We still listen to the community, but with the support of the model, it is more of a sure shot - it is a decision based on evidence and science."
>
> - Edwin Pinzon, IDRD

A descriptive model comprises the third component. Using multiple criteria for each Recreovía hub, the model estimates a single efficiency metric through Data Envelopment Analysis (DEA). The model is based on the BCC model (Banker, Charnes & Cooper, variable returns to scale) with interval data (Emrouznejad et al., 2012) to account for variations in inputs and outputs.

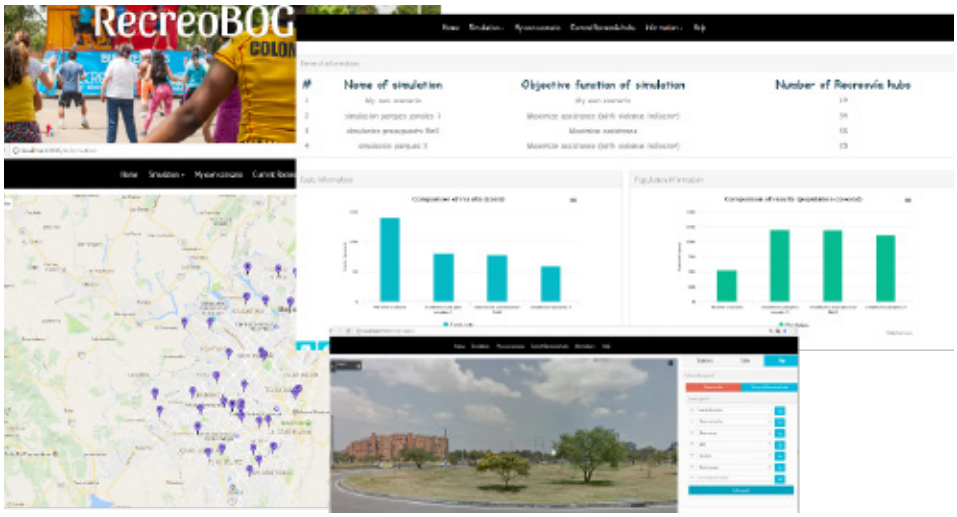

Fig. 2 Screenshots from RecreoBOG

The fourth component corresponds to a set of prescriptive location models that takes into account the predicted attendance, efficiency, theft ratio, operational budget, operating schedules, and the willingness to spread Recreovía hubs throughout the city. It is interesting to note that theft ratio was considered as a proxy for violence, since some candidate hubs were intentionally chosen in areas subject to violence i.e., areas that could benefit most from projects such as these. A couple of the location models provide robust solutions that account for the uncertainty in the attendance and efficiency estimates.

The fifth and last component integrates the location models into a Web-based tool, called RecreoBOG which facilitates the decision-making process. Fig. 3 shows some screenshots of RecreoBOG. Further technical details can be obtained from the references cited.

In February 2017, IDRD used RecreoBOG to aid the 2017 expansion planning. The team solved two robust location models – one focusing on attendance, the other

The co-authors of the full paper (left to right) O. L. Sarmiento, F. Solano, A. L. Medaglia, and L. Navas with C. Ribeiro (second, left to right) at the IFORS Triennial in Quebec City after receiving the IFORS Prize for OR in Development (2017).

on efficiency - with seven levels of the robustness budget, leading to a total of 14 instances. For each budget level, the model chooses a number of hubs (0, 5, 10, 15, 20, 25, or 30) that will underperform i.e., falls below the expected attendance by one standard deviation. A set of 19 Recreovía hubs out of 66 candidates consistently appeared in the solutions, accounting for about 60% of the identified new hubs under different scenarios. These 19 hubs were recommended to the IDRD officials in their expansion planning. Considering new budget realities and interactions with the community and local policy makers, the IDRD decided to open ten new hubs out of the 19 initially recommended. After the implementation of the new hubs, attendance has steadily increased. Total attendance data for all hubs from February to May of 2017 shows a compound monthly growth of 28% and an average per event attendance growth of 7%.

Citing benefits apart from the growth in attendance, Edwin Pinzon, the IDRD official tasked with expanding the programme through RecreoBOG says, "The tool has helped us to base our decisions on more solid ground and not just perception. Now we can avoid the expensive trial and error we used to do. We still listen to the community, but with the support of the model, it is more of a sure shot - it is a decision based on evidence and science. When a new park is opened, there is no doubt that the Recreovía programme needs to be there." Overall, the project has helped gain the attention of higher officials at IDRD and even the mayor's office, as well as engender trust on a programme that is based on data and an objective OR-based technology.

The authors (left to right) F. Solano (1), A. L. Medaglia (2, 2nd row), L. P. Navas (3, front row), A. P. Ríos (4, 2nd row), S. Abolghasem (5, front row), O. L. Sarmiento (6, front row), and with C. D. Bedoya (7, front row) at a joint COPA-EpiAndes meeting at Universidad de los Andes (Bogotá).

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Why Members Stay and Why they Leave

Octavio Peralta < obp@adfiap.org>

Editor's Note: Since IFORS is an Association of Associations, IFORS News features articles about association governance and management. In this issue, we feature an excerpt from the Business Mirror column (https://businessmirror.com.ph/why-association-members-stay-or-leave/) of Octavio "Bobby" Peralta who is concurrently the secretary-general of the Association of Development Financing Institutions in Asia and the Pacific (ADFIAP) and the CEO and founder of the Philippine Council of Associations and Association Executives (PCAAE).

A recent study on why members stay or leave their associations, commissioned by Community Brands and undertaken by Edge Research had some interesting findings.

Value proposition. The top reasons members decide not to renew are centered on dues becoming too costly and the organization providing little value.

Feeling connected. While majority of members (84 percent) feel satisfied with their membership, a far fewer (55 percent) feel a connection to their membership organization. This feeling could be related to other results:

Consistent Updates. Code of Ethics and consistent updates on industry information are must-haves to retaining members. Members look at their associations to represent members' interests, fuel growth and innovation, and raise awareness. Job, continuing education, and training opportunities are most important to millennial and Gen X members.

Frequency. However, the amount of information members want varies by loyalty level. Loyal members prefer detailed updates. Millennial and Gen X members are more likely to want more frequent communication. E-mail is the top-performing channel, regardless of a member's generation or level of commitment.

Type. Of the respondents, 74 percent recall being asked for at least some type of personal information or preferences. Of these, nearly half feel their content is not considered when materials are sent to them or when they are asked for the same data again.

The study lists where to go from here:

- Identify and understand your organization's loyalty segments. Educate your executive team and board of directors on the importance of these loyalty metrics, and start including them in your monthly or quarterly reports.
- Reevaluate your value propositions. Conduct member surveys and focus groups to identify the challenges your members face each day - how the organization might help and what tools are needed to be successful.
- Put your loyalty segments to work. Once you are aware of which members fall within each segment, partner with other stakeholders in your organization, including your marketing team, to build dynamic lists to successfully segment your various loyalty groups.
- Collect data and content preferences and use them. Members now expect organizations to collect information to personalize member experience.
- Keep your code of ethics updated and relevant. Members are proud to belong to an association that provides a framework and standard for their industry.
- Empower your "super members." Help your membership heroes use their power for good, and enlist them in helping move their peers up the loyalty spectrum. Committees, ambassador programs and advisory boards are great examples of bringing your super members together

Feature

Ten Years On: Considering Diversity In Assembly Lines

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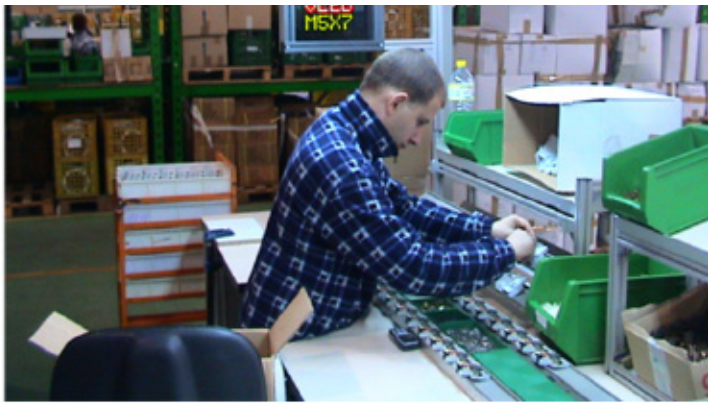
Inspired by the heterogeneous workforce at Spanish Sheltered Work centres for the Disabled (SWD), the paper *Advantages Of Assembly Lines In Sheltered Work Centres For Disabled* (Miralles et al., 2007) was the first to consider diverse worker paces and capabilities in planning and operating assembly lines. *The Assembly Line Worker Assignment and Balancing Problem* (ALWABP) developed was adaptable to a number of practical situations where an appropriate assignment of workers and tasks to stations could make disabilities invisible. This opened a research area for which a summary of work done in the past ten years is presented.



The original research was equally concerned with the maximization of productive efficiency as it was with respect for workers' limitations and their desirable socio-labour integration. Among the initial challenges involved consideration of job rotation as it becomes more crucial to minimize fatigue and ergonomic risks, while having to contend with task times that are different for each operator. Thus, the IP model and heuristic procedure of Costa and Miralles (2009) proposed to maximize the number of different tasks workers would execute in a complete rotation period, while maintaining the cycle time below a permissible slack with the same modeling framework. This was later used by Moreira et al. (2013), who proposed a hybrid solution method.

Further issues such as proposing alternative or complementary distributions that may provide extra possible assignments (and eventually rotations) to the serial configuration of ALWABP were addressed. The parallel/collaborative stations proposed by Araujo et al. (2012) proved to be a very useful approach. This was later generalized in Araujo et al. (2015), where

workers can be organized in as many stations and sub-lines as needed in order to minimize global cycle time. Likewise, the U configuration, that had been explored in Miralles et al. (2005) has recently been studied by Oksuz et al. (2017).

Another research line was devoted to extending the heterogeneous model from SWDs to regular industries, where workers with disabilities should comprise 5% of the workforce. Moreira et al. (2015a) defined the *Assembly Line Worker INTEGRATION and Balancing Problem* (ALWIBP) that minimizes the number of stations needed to achieve a desired productivity level while maintaining a minimum number of heterogeneous workers in the line. On the other hand, Moreira et al. (2017) proposed extensions that minimize the cycle time with a fair distribution of workers along the line, thus avoiding segregating clusters. Both papers showed that inclusion is possible with little or no productivity losses.

The intrinsic variability/uncertainty of certain parameters is another source of challenge in finding not only optimal but also robust solutions. Thus, after the Mixed Model ALWABP of Cortez and Costa (2015) for approaching products variability (to which Ramezanian y Ezzatpanah (2015) later added cost criteria) three main practical concerns have been modelled and solved:

- In Ritt et al. (2015) the eventual absence of workers, if predictable from records, is addressed by finding the best generic stable assignment of tasks to stations;
- To avoid workflow problems caused by the natural variability of manual processes, consideration of average times with robust approaches like those in Moreira et al. (2015b) is more reasonable than considering maximum task times.
- Hillier and Boling (1966) investigated the "Bowl Phenomenon" rule of leaving more idle time at central stations as an easy way of avoiding such problems. This is also noted for ALWABP in Castellucci and Costa (2015); whereas Zacharia and Nearchou (2016) propose a bi-criteria model for smoothing the workload along the stations.

In parallel, a transfer to related areas began with work like those of Benavides et al. (2014, 2015) or Fichera et al. (2017) that define new problems with heterogeneous workers at Flow Shop, Job Shop and Manufacturing Cells respectively. Another example is Carniel et al. (2015) which studied the integration of workers with disabilities into flow shops of ordinary firms.

During the past 10 years, modeling practical situations as given were complemented with research on new solution methods. The authors hope that more researchers in the OR community will work both on modeling and solving new features of this mathematically challenging and socially important problem.

Reference list can be requested from Cristobal Miralles, <cmiralles@omp.upv.es>

Book Review

Cutting Edge in a Neat Package

Hans W. Ittmann, University of Johannesburg <hittmann01@gmail.com>

Introduction to Cutting and Packing Optimization – Problems, Modeling Approaches, Solution Methods *by Guntram Scheithauer, 2018, Springer, Cham, Switzerland, pp. 410, ISBN 978-3-319-64402-8 (Print) and ISBN 978-3-319-64403-5 (eBook), 84.99 EURO (Hardcover), 71.39 EURO (eBook).*

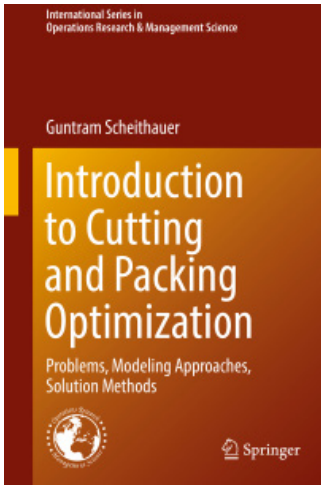
Cutting and packaging problems are encountered and occur in many different, everyday life situations. Placing clothes into a suitcase or food into a freezer are very mundane and simple examples. Allocation, cutting and packing problems comprise a wide variety of practical and theoretical problems. These problems are found in cutting paper, wood, glass, textiles, leather and footwear, plastics and metals while examples of packing are packing of bins, containers and pallets. Optimizing these types of problems are NP-hard and various methods, and techniques have been developed over many decades in order to obtain good feasible solutions. The book *Introduction to Cutting and Packing Optimization* provides a comprehensive overview of the types of problems encountered and their solution methods.

Two chapters deal with the general topic of modelling and quality restrictions while the rest of the thirteen chapters focus on specific problem types that include:

- Knapsack problems;
- Cutting stock and one-dimensional bin packing problems;
- One-dimensional cutting stock problems;
- Two dimensional knapsack problems;
- Optimal guillotine patterns of rectangular pieces;
- Non-guillotine patterns of rectangular pieces;
- Two dimensional bin packing;
- Pallet and multi pallet loading problems;
- Packing of rectangles into a strip;
- Container and multi container loading problems;
- Packing and allocation of polygonal pieces and objects; and
- Circle and sphere packing.

Formulation of the above problem types involves either maximizing material utilization or minimizing the material usage. For example, in cutting round timber or logs, wood utilization is maximized while for steel pipes, steel usage is minimized.

The introductory chapter outlines frequently-used models through examples of set-theoretical, nonlinear optimization, and integer linear programming models. Chapter 2 presents approaches to the knapsack problem, namely the Gilmore and Gomory algorithm, the longest path method, and a number of algorithm extensions to the knapsack problem. The succeeding two chapters present, in turn, the one-dimensional bin packing and one-dimensional cutting stock problems.



Orthogonal packing feasibility and orthogonal or two-dimensional knapsack problems are the focus of Chapter 5. Both of these are basic problems in two- and higher dimensional cutting and packing, where a set of d-dimensional rectangular items need to be packed into a given container and rotation is not allowed. Methods to solve these kinds of problems include nonlinear and integer linear programming models.

Other topics considered here are the necessary conditions for feasibility of the orthogonal packing problem, a graph-theoretical approach, and a branch and bound algorithm that allows for additional restrictions and heuristic methods to solve the problem. In Chapter 6, guillotine cutting is introduced where the desired product is obtained from a number of guillotine cuts. A variety of ways in which guillotine cuts can be used to obtain the desired pattern for knapsack-type and cutting stock problems are presented.

Chapters 7 and 8 are, respectively, on packing rectangles into a strip, and the two-dimensional bin packing problem. Since strip packing problems are NP-hard, heuristics are introduced. At this point, the need to distinguish between optimization problems where all the input data are known (*offline type*) and those for which not all input data are available beforehand (*online type*) is emphasised. Another cutting and packing aspect introduced in Chapter 9 is on heterogeneous materials, or materials with forbidden regions, i.e., where parts of the material may not be used because of quality concerns as in leather from animal skin.

Interesting examples of cutting and packing problems are tackled from Chapters 10 to 13, including: pallet loading, container loading, packing of polygonal pieces and circle and sphere packing. The manufacturer's pallet loading problem is differentiated from that of the distributor's owing to the difference in the box-shapes. Manufacturers have identical box-shaped pieces while distribution centres would have different shaped box-types. The differences in formulations and solution approaches are discussed.

Container loading and pallet loading are shown as similar optimization problems. However for containers, many different box types need to be considered, where the problem can be stated as: given a set of *m* different types of pieces or boxes with related availability and value coefficients, and a box-shaped container, find the packing pattern of maximal total valuation. A basic algorithm is discussed with additional heuristics to solve it. Further extensions to multi-container loading and three-dimensional bin packing are described as well as the model formulations and solution approaches.

In Chapter 12, packing polygonal, non-rectangular, pieces on strips with both convex and non-convex objects is outlined and with rotation of objects allowed. Various methods of addressing these complex problems and different algorithms to solve them are discussed. Chapter 13, on circle and sphere packing, considers five types of problems: (i) packing circles into a circle; (ii) packing circles into a strip; (iii) packing identical circles into a circle; (iv) packing identical circles into a square; and (v) packing identical circles into a rectangle. For each one, the model is formulated and solved with examples. Lastly, sphere packing is discussed.

Most of the chapters start with a problem statement and illustrated with examples. At the end of each chapter, there are numerous exercises with accompanying solutions. This is extremely useful for those who work in this area and those who wish to familiarise themselves with cutting and packing optimization problems. In both instances, it deepens the acquired knowledge.

For an introductory book to cutting and packaging optimization, it offers more with its excellent overview of the broad spectrum that comprises the cutting and packing problem scope. The book delves into details and it provides a comprehensive treatment of appropriate modelling approaches and solution methods of the problem types presented. The strategy of first addressing simple problems and then building up to the more complex ones is an effective teaching and learning strategy. This makes the book a valuable source of fundamental knowledge and latest research results for students, practitioners, and researchers who find themselves facing cutting and packing challenges.

Bearing Fruit After Years of Hard Work

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Conspicuously missing from the roster of International Federation of Operational Research Societies (IFORS) members, and by extension, its European grouping, the European Association of Operational Research Societies (EURO), has been the national society of Russia. Owing to the efforts of a working group, Russian Operational Research Society (RuORS) finally came into existence.

Profs. Nurminskiy and Mazalov discuss business on the coast of Baikal lake.

The discussion about creation of RuORS was initiated during the 7th Moscow International Conference on Operations Research (ORM 2013) on October, 17, 2013 by Vladimir Mazalov and Alexander Vasin. The IFORS News issue of December 2013,p.5) states:

The Russian Scientific Operations Research Society was established in 1996 during the very first conference. The conference has since taken place every three years. As in the past, this seventh conference provided an opportunity for personal and scientific exchanges as well as strengthening of scientific networks. Among matters discussed was the establishment of a new Russian Operational Research Society (RuORS) for which much work has already been done.

The decision to create RuORS and to apply for IFORS membership was accepted during ORM 2016 on October 20, 2016. The special talk of the EURO Vice-President Silvano Martello on EURO and IFORS activities was part of the conference program. Since that time, the working group started to develop the required documents and to contact Russian scientists on their thoughts about the RuORS membership in the IFORS and EURO. It was at this time that the RuORS site (ruors.ru) was created.

The general RuORS By-laws were developed and posted on the site. This contains the main purposes of RuORS which are:

- To encourage theoretical and applied research in the field of operations research;
- To promote information about the achievements of operations research through conferences, workshops, magazines, books, email, and the internet;
- To promote international connections and enlist the support of the Russian scientists and experts who work in the field of Operational Research; and
- To uphold the rights and interests of its members.

By December, 2016, 56 Russian scientists supported RuORS organization and its application for IFORS membership. On December, 9, 2016, the working group sent the Application for Membership to IFORS. IFORS members then voted the RuORS national society into IFORS membership. On July, 18, 2017, RuORS was accepted into IFORS and acknowledged by IFORS President Michael Trick, "as our most recent national member society of IFORS."

The first General Assembly meeting of RuORS was held during the 17th Baikal International Triennial School-Seminar themed "Methods of Optimization and Their Applications" on August, 4, 2017. During this meeting, Vladimir Mazalov recounted the history of RuORS: its creation and the important role of the General Assembly. During this first session of RuORS General Assembly, members accepted the RuORS Statutes, made decisions on the Directive Board and the Board Members, and decided on the normal individual dues for RuORS members.

Other important decisions made during the meeting were to assign the Directive Board to develop the Application for Membership to EURO and to encourage RuORS members to hold Russian Conferences on OR under the aegis of RuORS.

With a current membership of 77 Russian scientists, RuORS hopes to be able to play an active role in the national OR stage and become an active, contributing member of IFORS and EURO!

CALL FOR PROPOSALS TO HOST THE IFORS 2023 TRIENNIAL CONFERENCE

IFORS has grown rapidly worldwide in terms of total membership, number of member national societies and the profession and practice of Operational Research. The Triennial Conference has been a key factor in this growth and is IFORS' most important single event.

Purpose of the IFORS Triennial Conference

- provide a means for exchange of information on Operational Research topics between nations;
- provide exposure to IFORS on a rotating basis among the major geographic regions where IFORS has member societies;
- encourage the establishment of national Operational Research societies; and
- promote the development of specific parts of Operational Research, for example, to ensure a balance or to open up new fields

Preparing a Proposal to Host the IFORS Conference

Letters of Intent for undertaking a Triennial Conference must be received by the IFORS Secretariat approximately 5.5 years before the actual Conference: for instance, for the 2023 conference, the Letters of Intent must be received by January 31, 2018. The full written proposal will be due two months later, on March 30, 2018. Please contact the Secretary of IFORS to obtain the current Meetings Manual (secretary@ifors.org).

The proposal to become a Host Society must include all of the following information:

- o Alternative sites for the meeting in the host country (advantages, facilities, and accommodations, meeting rooms, typical room rates at conference hotel, nearby low-cost housing for students) and an approximate date for the conference;
- o Names and backgrounds of members of the Local Organizing Committee who will have responsibility for planning and managing the conference;
- o Rough draft budget, identifying the proposed conference fees;
- o Adequate assurances that IFORS will not be subject to any financial losses because of selection of a particular host country, and will be able to achieve an appropriate financial return from the conference (a letter from the President of the Society acknowledging fiscal responsibility to accompany the proposal); and
- o Reasons for holding an International Conference in the particular country in the light of IFORS objectives stated above.

Selecting a Host Country

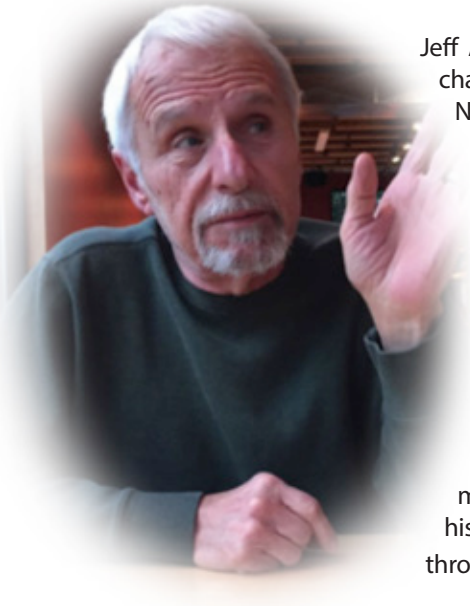
The IFORS Administrative Committee will review all submitted proposals, The accepted proposals will be presented to the Representative Societies of IFORS for a mail vote. Three months will be allowed for each vote but the successful society must receive at least half of the votes cast. Should this not occur on the first ballot then a second vote will be taken between the top two candidate societies.

The result of the ballot will be sent to all Representatives and the selected Host Society will be informed to proceed with arrangements. Conference preparations may start immediately after written notification of selection.

Obituary

Jeff Arthur (1952-2017)

Adapted by Graham Rand <g.rand@lancaster.ac.uk>
from an Obituary published in OR/MS Today



Jeff Arthur, Professor Emeritus of the Statistics Department at Oregon State University, who chaired the Organising Committee of the 2005 IFORS conference, held in Hawaii, passed away Nov. 12, surrounded by loved ones. He was 65.

Professor Arthur was a member of the INFORMS Meetings Committee for many years. Meetings Committee member Jeff Camm, states: "[Jeff Arthur's] passion for the profession improved INFORMS meetings, but his love of people and his love of life are what I will remember most about him. He had a wonderful way of making any meeting fun. He treated everyone with respect. He will be greatly missed."

His research interests included mathematical programming and applications, computational aspects of optimization, and optimization modelling of environmental issues.

Professor Arthur attended Purdue University where he received a bachelor's degree in mathematics, and his master's and doctorate degrees in operations research. He then shared his knowledge and passion as a professor in the Statistics Department at OSU from 1977 through 2011.

Tutorial

Locating Beehives for Optimum Pollination

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Andrew Lewis, Simulsys Ltd, Chelmsford <andy.lewis01@gmail.com>

Introduction

Food production is to a large extent dependent on pollination. However, pollinators such as honeybees, bumblebees, solitary bees, hover flies, butterflies and other wild pollinators are being lost at an alarming rate due to loss of habitat, disease [1], and excessive use of pesticides and in particular neonicotinoids. Indeed, a recent report by the European Food Safety Agency concluded that some pesticides posed a high risk to pollinators such as honeybees [2]. As a result, honeybees are becoming an increasingly scarce resource. An effective use of this resource is therefore in order. This tutorial describes an optimization approach to deploying honeybees in an effective way for pollinating fruit trees and other flowering plants.

Pollination with honeybees to boost crop yield is not new. Current practice consists in beehives arriving on trailers and left on them on the edge of the fields where the plants to pollinate sit. This approach is convenient since the beehives are all kept together and the trailers are simply stowed away at the end of the hire period. But, pollination leaves distant parts of the fields uncovered. The number of needed beehives may well be overestimated too, which will impact negatively on pollination elsewhere, since there are not enough bees to go around. It is, therefore, necessary to look at this decision-making problem from a systematic viewpoint, so that appropriate positions for the beehives can be found and only the necessary number of beehives are used. The approach expanded here advocates the placement of beehives among the trees and plants where they are needed. Their number and locations are defined based on the area of the field, the number of plants to pollinate and the distance a bee will cover to forage.

The beehive location problem

The Beehive Location Problem (BLP) seeks to place the least number of beehives to pollinate a given number of trees. An alternative definition may describe it as the problem of placing strategically any available beehives for most effective pollination. This latter definition requires an extra constraint on the number of available beehives.

The problem can be complicated in that no two orchards are identical: trees may be old and large or may be small and densely planted as in modern orchards; some may have obstacles that will hamper a regular distribution of the beehives; others may have neighbouring fields covered in flowering plants which will attract the bees. It is also important to take into account the risks of deploying bees in the vicinity of urban areas. Bees themselves may behave differently depending for example on their type or the size of their colony. In its most general form, taking into account all aspects including the weather, the problem is highly intractable even for modest size instances. A model is developed below for the most basic case.

Optimisation model

Suppose that the trees to pollinate are randomly located in a flat polygon-shaped field. Assume that the bee colonies are of the same size and that any tree within foraging distance of the bees in a hive will be pollinated. Every hive used has a cost. The aim is to pollinate all trees at minimum cost.

In this form, BLP is the Set Covering Problem (SCP), [3], [4], which is the problem of covering a subset of objects from a larger set N with other subsets B_j of N at minimum cost since each subset B_j has cost c_j. Note that SCP is NP-Hard, [5].

As an SCP, the subsets of beehive locations which would cover all the trees must be defined. Assuming that a bee may visit any tree within a circle of radius R, no beehive will be needed within the radius R of a tree with a beehive at its foot. It is, therefore, necessary to identify all trees within the distance R of each tree. For this, distances separating the trees and an assumed value for R are needed.

Let there be n trees numbered from $i=1$ to n. Let B_j be the set of all trees within distance R of tree Tj. There are n such sets B_j, $j=1,\ldots,$ n. Let D be the matrix of distances d_{ij} between trees i and j, with $i \neq j$ and $d_{ii} = 0$.

$D = (d_{ij}, i=1,..,n, j=1,..,n)$.

It is possible to find all sets B_j, $j=1,..,n$. From these subsets, it is also possible to find a (0, 1)-matrix which indicates to which subset(s) B_j a given tree i belongs;

$A=(a_{ij}, i=1,..,n, j=1,..,n)$, where $a_{ij}=1$ if tree i is in subset B_j and 0 otherwise. Define

$$x_j = \begin{cases} 1 \text{ if } Bj \text{ is in the cover, i. e. if we place a beehive at the foot of tree } j \\ 0 \text{ Otherwise} \end{cases}$$

The optimisation model is as follows.

(1) Minimize $\sum_{j=1}^{n} c_j x_j$

(2) Subject to $\sum_{j}^{n} a_{ij} x_j \geq 1$, for $i=1,\ldots, n$

(3) $x_j \in \{0,1\}, j = 1,\ldots, n$

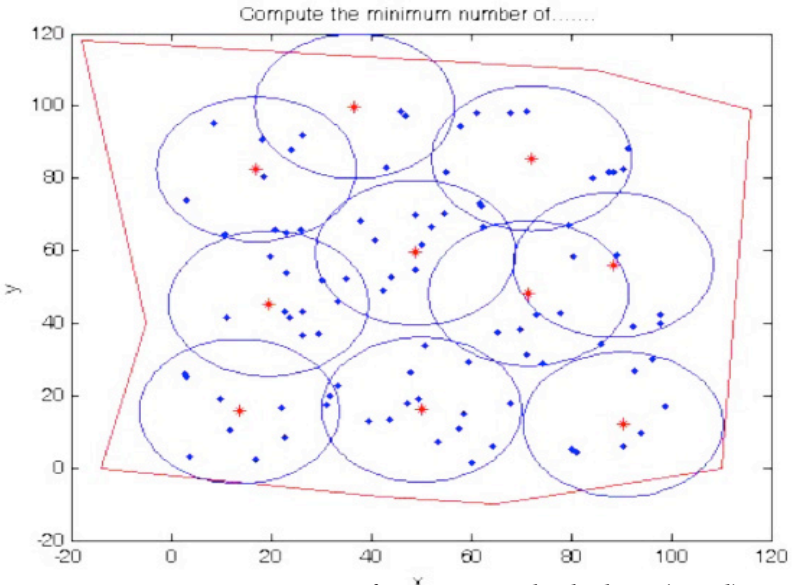

Figure 1 *Minimum cover of a 100 trees with 9 beehives (in red)*

Figure 2 *Practical application on a farm in Chelmsford, Essex, UK.*

where (1) is the objective function which minimizes the cost, (2) ensures that every tree i must be covered by at least one beehive and (3) to indicate that the decision variables are binary. Other constraints may be added as necessary.

An instance of the problem with 100 trees randomly generated in a 100x100 m2 grid, and a foraging distance of 20 metres was solved in Matlab. The results are represented in Figure 1. Results on an application of the model to real data are shown in Figure 2.

Conclusion

Essential for food security, honeybees are becoming scarce for many reasons. While it is important to save them, it is also important to use them efficiently to improve crop yield. Though NP-Hard, the Beehive Location Problem may be solved to optimality in reasonable time as a Set Covering Problem for practical instances. Admittedly, many parameters have to be taken into account thus calling for a more comprehensive model to deal with this issue.

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IFORS NEWS Editor in Chief: Elise del Rosario