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ORSSA Newsletter June 2018

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FROM THE EDITOR

By *BRIAN VAN VUUREN*

(*brianjohnvanvuuren@gmail.com*)



Brian van Vuuren

Dear ORSSA Members

Every time I finish up with a quarterly newsletter, I always think: “*well - I won't be doing this again for some time...*”

And then, before I know it, here I am writing the next editorial piece. Time really does fly and it's hard to believe that we are already half way through the year! I trust everyone has had a productive, engaging and enjoyable first 6 months of 2018 and that there are great things planned for the remainder of the year!

In this quarter's edition, we focus in on the **Pretoria chapter** (hence the cover image) and review some of the events they've been enjoying, as well as get to know a few of their chapter members. We'll be aiming to profile each chapter in newsletter editions to come, so please keep an ear to the ground for when it's your chapter's turn. It would be a great time to contribute a piece! A special thanks to Sumarie Koetsier for her tireless work in putting together the bulk of the articles which appear in this June edition. In addition - thanks to the other authors who took time to make contributions. Unfortunately our puzzle master, Shane van Heerden, is away on an exchange program in Sweden at this time and so this quarter's edition is short of a brain-busting puzzle. We'll hopefully have more intellect-insulting riddles or puzzles once again, come the September edition.

As mentioned in my previous editorial, I've taken on a new job in a virtually new field in 2018. Initially, I'd been highly motivated to take on this role because I wanted to be exposed to a brand new environment which required me to learn new skill, new jargon and new software. I likened the experience to that of the beginning of my postgraduate studies; where I had no idea what I was doing or how I would do it, but I just 'got going' – forging my way, bumping my head, and figuring things out, slowly but surely.

I remembered the satisfaction of finally mastering a new skill and software, of possessing the ability to translate my thoughts into models or code. To imagine a solution approach in my head, and then be able to build the corresponding model with a relatively high level of competence. The part that I was conveniently forgetting, however, was the tiring, painful journey which precedes arrival at that destination of competence!

Learning is a slow and often painful journey. It requires of us to 'keep our heads down' and commit wholeheartedly to mastering the new skill at hand (in my case, it helps to stay

motivated when your paycheck depends on it!) And the temptation is often there to simply return to what we know – what we're good at – to feel 'useful' and 'accomplished' again.

But, in a profession such as ours and in a world such as this, such an attitude will never do. You may not be entering a new field professionally, but we all know that we need to continually challenge ourselves and develop new competencies in the fields in which we presently work. With new developments around every corner, and more and more attention, resources and efforts being directed towards operations research (and the associated fields) worldwide; we need to rekindle and relish our ability and passion to learn. We need to remember that nothing worth having comes without some kind of fight and that, with enough perseverance, we will return to that place of feeling capable and accomplished. And when we get there, we'll look back and think, “what a privilege it is to be able to keep learning!”

Enjoy the newsletter.

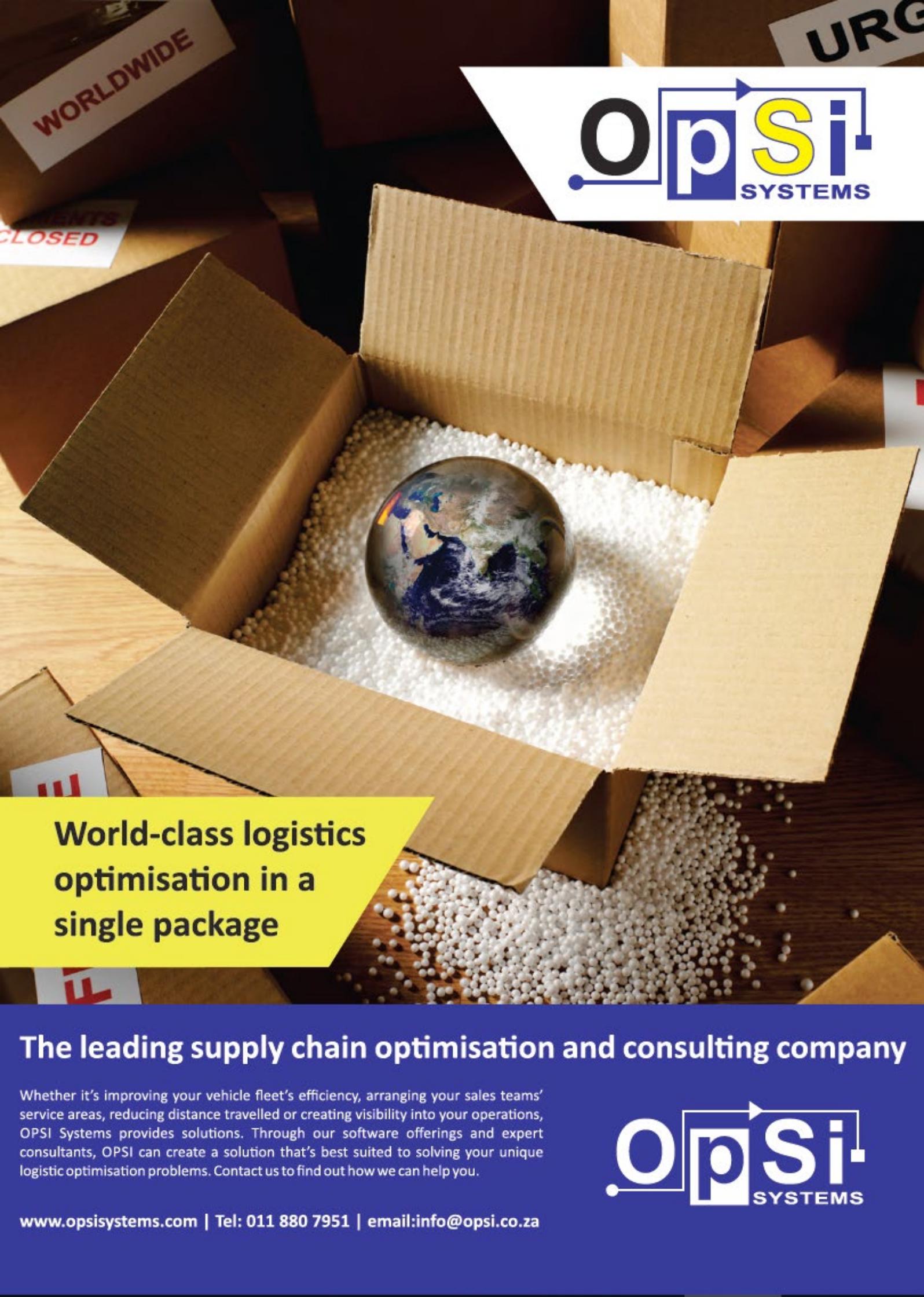
Until next time, ,
Brian

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FROM THE PRESIDENT'S DESK

By DANIE LÖTTER

(DANIELOTTER@SUN.AC.ZA)

ORSSA PRESIDENT



Danie Lötter

Greetings to all ORSSA members. The second edition of the annual Newsletter marks the end of the first semester of 2018 which arrived at a breathtaking pace. I trust that everyone had a busy, yet productive, first semester and that you are looking forward to the second half of the year.

This is also the final edition of the Newsletter that you will receive before we meet for the annual conference in September. As always, the annual conference is one of the highlights on the ORSSA calendar and this year's conference is scheduled to take place from 16-19 September at the CSIR in Pretoria. It is organized by the Pretoria chapter and is spearheaded by the local organizing committee chair Sumarie Koetsier. I would like to thank Sumarie and the rest of the local organizing committee for the sterling job they are doing in organizing this year's conference. I would also like to extend a special word of thank you to the sponsors who made a contribution to help make the conference a success. They are, thus far, OPSI systems, the Department of Statistical Sciences at the University of Cape Town, the Centre for Business, Mathematics and Informatics at Northwest University, Bluestallion Technologies and the Department of Industrial Engineering at Stellenbosch University.

Registrations for the conference are well on their way and I would like to urge members to register for the conference and to submit their abstracts for presenting their work. The closing date for abstract submissions is approaching fast and members have until 22 July to submit their abstracts. Prospective delegates who would like to make use of the discounted early-bird registration fee have until 7 August to register and pay for the conference.

The local organizing committee invited two very well-known OR practitioners to deliver keynote addresses at this year's conference. The first is Liezl van Dyk (executive dean at the faculty of Engineering at Northwest University) and the second is Charles Malack Oloo (president of the African Federation of Operations Research Societies). I look forward to their keynote addresses.

By now, you should have received a statement from the treasurer providing you with your outstanding membership dues. I would like to request all members to please pay their membership fees at their earliest convenience. Any questions or queries with respect to your statement may be addressed to the national treasurer Christa de Kock. She may be contacted via electronic mail on treasurer@orssa.org.za

I would also like to thank each member who has made a contribution towards the Society thus far. Member input and contributions is the lifeblood of the Society that keeps it at the forefront. Finally, I would like to extend a friendly invitation to members of the Society to contact me should they have any suggestions as to how ORSSA can improve on the service it delivers to its members.

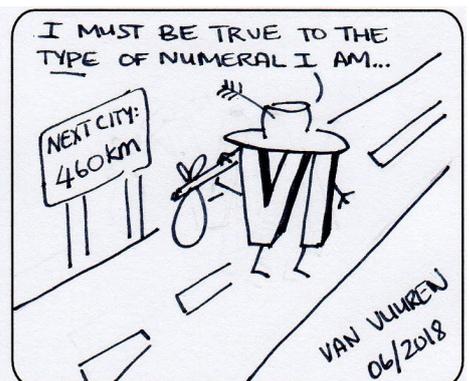
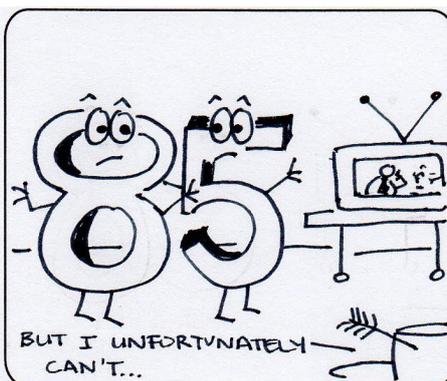
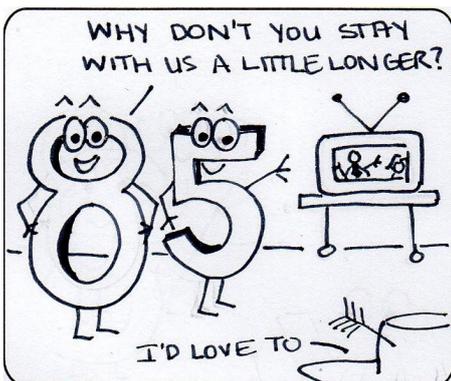
With my best wishes until we meet in Pretoria in September

Daniel Lötter

HAVE YOUR SAY

The ORSSA Newsletter is an excellent medium for showcasing one's work or interests to the Operations Research community, not only in South Africa, but around the world.

Contributions of any nature are welcomed. If you would like to submit material to the Newsletter, please send your article or review, along with all associated media (e.g. images, charts, etc.) to the editor at brianjohnvanvuuren@gmail.com



GETTING TO KNOW THE PRET{OR}IA CHAPTER*Compiled by Sumarie Koetsier (sumarie.koetsier@gmail.com)*

Leon Uys

I recently asked Leon Uys, Technical Project Manager at Resolve Solution Partners, to answer a few questions so that we can get to know him a bit better. Leon is often busy behind the scenes helping out with the Pretoria Chapter events as a member of the ORSSA Pretoria Committee. I thought it's high time we shine the spotlight on such a valuable team member.

When did you first become interested in Operations Research?

In 1998, when I was working on the National Empty Wagon Distribution project for my bursary holder Spoornet.

What is your current position at Resolve? Does your current role require you to use operations research techniques frequently?

I am the Technical Project Manager. I am not using enough operations research techniques to my liking, no. I provide technical grid computing environments for planning systems in the Vehicle Routing Problems environment for one of the biggest South African retail businesses - they keep us very busy!

Which OR topic do you find most interesting and why?

My passion is still Vehicle Routing Problems (VRP) and during my previous life at IMPERIAL Logistics we delivered various solutions for Logistics Subsidiaries and their principles.

Looking back on your career, what is the most interesting**OR-related project you've been involved in?**

There isn't a specific project that comes to mind, but I must say, if it had wheels I was interested! I always aimed to reduce the orders to cash cycle regardless of the type of logistics problems. System integration has been and will always be a big challenge and always remains interesting.

You've been a valuable member of the ORSSA Pretoria Committee for many years. When did you become involved in the Chapter's activities and what motivates you to stay involved?

After attending a couple of ORSSA events I got hooked and got involved with the Pretoria Committee in April 2014. The various facets of OR applied and different disciplines and industries using OR intrigues me. Also, the fellow committee members and their passion and dedication for the Pretoria Chapter keep me motivated.

I would like to thank Leon for his continued support of the Pretoria Chapter, and for ensuring that our chapter events run smoothly. If you would like to connect with Leon, you can find him on LinkedIn (<https://www.linkedin.com/in/leon-uys-804a03/>)

A new Pretoria Chapter Committee is elected each year at the Chapter's Annual General Meeting. If you are interested in serving on the committee, please don't hesitate to join us at the next AGM at the end of this year. We are always looking for willing and able candidates, such as Leon, to join our committee and serve the ORSSA Pretoria Chapter members.

INFORMS CONFERENCE FEEDBACK*Compiled by Angela Rademeyer (angela.rademeyer@gmail.com)*

Angela Rademeyer

Most of us have heard of the INFORMS conference, but very few have actually managed to attend. After Angela Rademeyer and colleague, Raquel Morgan, attended this year's event, Angela wanted to provide some feedback on the experience to enlighten potential future attendees:

What, where and when was the conference?

INFORMS annual business analytics conference, April 2018, Baltimore MD.

How did you hear about the conference?

I am an INFORMS member and have always wanted to attend one of their events.

What were your expectations of the conference going in?

We were hoping to hear from large international corporations (and American government agencies) what their authentic experience has been in implementing OR and machine learning models - have people really achieved what online articles claim is happening in industry. It was also tipped to be a great chance to meet new software vendors (and their clients) and discuss the softer issues of ethics, presentation techniques etc.

Did you present? If so, what did you present on?

We didn't present but are certainly keen to do so if we are able to attend again. The standard of work we see in SA is more than adequate to present internationally.

Were there any other South Africans present at the conference?

We met some ex-pats, but that's all.

Who were the plenary speakers? How were their talks?

- Bill Schmarzo (*CTO IoT and Analytics, Hitachi Vantara and University San Francisco, School Of Management Executive Fellow*).
- *Title:* Big data MBA: What is the value of your data?
- His talk mainly focused on 3 things: (i) companies including big data as part of their strategy as opposed to having a separate big data strategy, (ii) how big data is allowing us to make things small; personalisation, biases, preferences etc and (iii) how big data is a re-usable asset with a network effect.

- Bruce Greenstein (*HHS Chief Technology Officer*)
- *Title:* From Data to Analytics -How to Solve Complex Health Problems
- The US Department of Health and Human Services is the largest government agency in the world. They have had success in combatting the opioid crisis by running a code-a-thon and by opening up their data across government departments. They will also be releasing some data to the public in future to assist in fraud detection.

What other interesting talks did you attend?

The most unusual talk was by a company called Virtualitics (<https://www.virtualitics.com/>). They have built a

VIP - Virtualitics Immersive Platform - which is the first collaborative data exploration platform that merges AI, big data and mixed reality. The platform allows for a new ways to present data through smart mapping – so there's an element of dimensionality reduction along with virtual reality data visualisation.

How did you find the other conference attendees?

We found people to be very open in sharing their project details, experiences etc which was refreshing.

What social opportunities were offered at the conference?

There were many different events organised such as first timers cocktails, coffee with CAPs and the premier event being the Edelman gala.

How was the city in which the conference took place?

Baltimore was hosting an event the week we were there called Light City, which was a festival of light, music & innovation. There were light installations all along the inner harbor walk and it was a great spectacle. Baltimore is also less than an hour away from Washington DC so we were able to experience the annual cherry blossom festival the weekend prior to the conference.

Would you recommend ORSSA members consider attending this conference in the future?

Definitely – INFORMS hosts 3 major conferences per year, the other 2 being more academic focused.



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ORSSA PRETORIA CHAPTER:

A SNEAK PEAK INTO THE BI-WEEKLY LEAN ANALYTICS MEETUPS

Written by Sumarie Koetsier (sumarie.koetsier@gmail.com)

Sumarie Koetsier

Before work on a cold winter's morning I arrived at Seattle Coffee Company in Lynnwood to attend ORSSA Pretoria's Lean Analytics Meetup. For those who don't know, Meetup is an online platform where you can arrange social or professional gatherings around shared interests. In our case, this is Operations Research. After the success of the Jo'burg Chapter's Lean Analytics Meetups¹, the Pretoria Chapter² (and more recently, the Western Cape Chapter³) decided to follow suit and start their own meetup groups.

Once everyone arrived and got their coffee, we sat down to start the discussions. We noted down different topics and questions onto Post-it notes. Every meetup is different because attendees can write down any OR-related topic, or question they might have. Since different people attend each week, it keeps the conversations fresh and interesting as each person brings their unique perspective and experience to the discussions. The Pretoria meetup has had students, lecturers, researchers, consultants, retired OR professionals, and entrepreneurs from many different industries join, resulting in a lively discussion each time.



Chapter members discussing various topics over coffee

We only had three topics at this meetup, which were “Computerised Adaptive Testing Web Apps”, “Updating T's & C's of Privacy Policies”, and “Crowdsourcing Travel Data”. We started off by discussing ways in which one can develop a computerised adaptive web application which is able to collect data from the user and predict some outcome based on the user's responses. Reference was made to *Flask*, a Python microweb framework, and we went into the details of developing and deploying an *R Shiny* app. We also discussed the sensitive user-generated data that can be gathered from this app, which led to the next topic: the recent updated terms and conditions of major companies' privacy policies.

These updates came into effect in May following on Europe's new General Data Protection Regulations, which

require companies to declare what data they collect from their users, and also why they collect these data. Companies are now also prevented from storing user data for longer than five years, and users can request companies to permanently delete their data. While these updates were made to protect users, there are also drawbacks to the new policies. When building predictive models to better understand their users, companies use user-generated data to feed into their models. When large chunks of their datasets are now removed, biases may be created. Law enforcement may have previously used browsing data to identify criminal activities, but now criminals have the means to delete their online tracks. Requesting that your data be deleted may also count against you in some instances, as your data may have been used to approve you for a desperately needed loan. As a credit company will now be unable to access certain personal data on you, they might reject you based on that lack of information.

We also spoke about the reliability of crowdsourcing data versus setting up expensive surveys or interviews to better understand behaviour. We spoke about different techniques to crowd source data, such as gamification, and the quality of data collected using crowd sourcing techniques. I don't know how we got to this point, but the discussion naturally evolved into a new topic: “AI developing AI”, and the implications this may have for society. This just shows what a great platform the meetups are to network with other OR professionals, as every person can ask questions and share information freely.

I would like to thank Quintin van Heerden for consistently hosting the ORSSA Pretoria Lean Analytics Meetups, thus promoting Operations Research in the Pretoria area. The Pretoria Chapter's meetups are held every second Wednesday, from 07h30 at Seattle Coffee Company in Lynnwood while the Jo'burg Chapter's meetups are held every alternate Wednesday from 07h30 at Starbucks in Rosebank, and the Western Cape Chapter's meetups are usually held over lunchtime at the Neelsie Student Centre in Stellenbosch. All the ORSSA Lean Analytics Meetups are open to the public, and if you would like to join one of these events simply sign up as a member on the respective Meetup pages to be notified of the next meetup that will be held in your area.

¹<https://www.meetup.com/Lean-Analytics-ORSSA-PTA>

²<https://www.meetup.com/Lean-Analytics-ORSSA-JHB/>

³<https://www.meetup.com/Lean-Analytics-ORSSA-STB/>

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DATA SCIENCE 101: A JOINT DATA SCIENCE EVENT

Written by Sumarie Koetsier (sumarie.koetsier@gmail.com)



Sumarie Koetsier

This event is part of a Data Science Seminar Series jointly hosted by ORSSA (Pretoria and Jo'burg Chapters), ICCSSA, SASA and SAS. A number of data science seminars will be held throughout the year, rotating the responsibility of hosting each event between the societies involved.

On Thursday, 10 May, the ORSSA Pretoria Chapter held a joint event with ICCSSA (Institute of Certificated and Chartered Statisticians of South Africa), SASA (South African Statistical Association) and SAS. It was held at Resolve Solution Partners in Samrand. The event was attended by 30 people, split between ORSSA, ICCSSA and SASA members.

people's lives. Care must therefore be taken when applying these algorithms, and we must not forget that someone's life will, in one way or another, be impacted by the results of our cleverly designed algorithms.

There is, of course, also a lighter side to AI. An example used by Brian is a tic-tac-toe game, where algorithms are given a huge grid on which to play the game. After a number of rounds, developers found that one algorithm was on an unprecedented winning streak. Upon further investigation, it was found that the algorithm learnt to make a move on the furthest block available on the grid, causing the opponent to run out of memory whilst trying to calculate a countermove.

“Currently many topics like Data Science, Decision Sciences, Big Data, Machine Learning, Artificial Intelligence and related topics, are of interest to various researchers, consultants, academics and industry. Hence strategic discussions are being held with the Operations Research Society of South Africa (ORSSA), the South African Statistical Association (SASA) and SAS Institute to hold joint seminars, thereby attracting a wider audience. The joint seminars also help in providing more frequent seminars while reducing costs to each of these organisations. The focus at the moment is in the Gauteng area and therefore the ORSSA Pretoria Chapter, ORSSA Johannesburg Chapter and SASA Gauteng Chapter are involved. If this initiative is successful, similar joint seminars can be set up in other regions using ORSSA and SASA's chapters and SAS regional offices.”

– Dr Pravesh Debba, Chairperson: ICCSSA

The first talk was titled *“Data is all around us: A tour through many of the concepts and terms that we encounter every day”* and was presented by Brian Stacey from Resolve. Brian has many years experience in the information and technology industry. Over this time, he has developed a passion for the creation of business value through the exploitation of the data available - and the current growth trends in information gathering and analytics provide ample support for his vision.

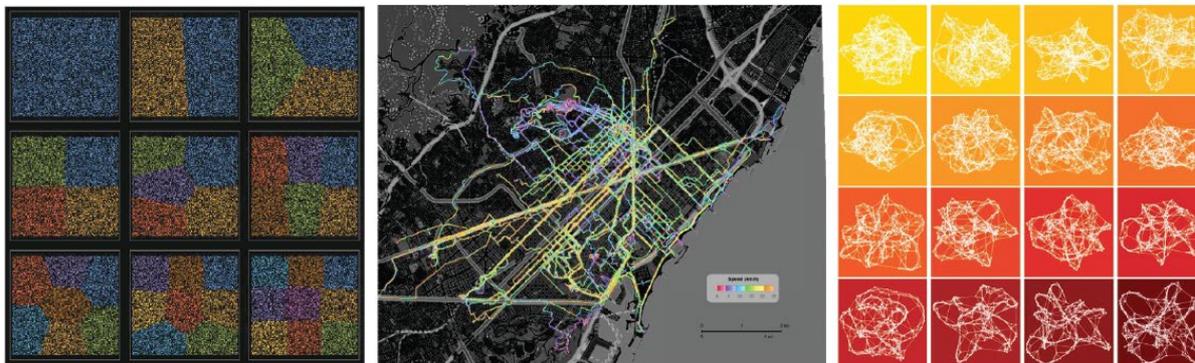
Brian's talk touched on many data science-related topics. These included such the exponential growth of data, how data are continually being generated and consumed, to reach the eventual goal of improving insight and decision-making. Some of the opportunities, as well as pitfalls, of data science, data-driven decisions, artificial intelligence and data lakes were explored.

A number of interesting points were raised by Brian, such as the challenges of artificial intelligence (AI). He mentioned a book by Cathy O'Neil titled *“Weapons of Math Destruction”*, which was also showcased on a TED Talk¹ and reviewed in the March 2018 ORSSA Newsletter. In her book she explores the dangers of blindly applying artificial intelligence and that (unbeknown to most) these algorithms can play a significant role in the trajectory of

Oftentimes, the solutions provided by these algorithms are contrary to what the developers of the problem would expect. But this is probably exactly what you want from a machine learning algorithm: learn the rules of the game as quickly as possible, and come up with a whole range of solutions to solve the problem. Machines aren't bound to frames of reference in their “thinking” as humans are, therefore in many cases these algorithms are sometimes exactly what is required to come up with innovative solutions. The trick is for the developers to set the rules of the game as practically as possible so that the algorithms do not find a loophole that will result in solutions that are impractical or infeasible to implement in reality.

The second talk was presented by Andrew Stephens (also from Resolve) and was titled *“Practical analytics in supply chains: How to use your data to make business better”*. Andrew has over 20 years experience in the supply chain industry. He started the Analytics-as-a-Service business unit in Resolve years ago with the objective of assisting clients in unlocking value with their data. It was clear from Andrew's talk that his years of experience have taught him the art of using a client's data to convince them that something needs to change in their day-to-day operations, and that these changes have significant impacts on their bottom line.

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Andrew discussed the step between reporting and data science - practically using data in better ways through visualisation and general analytics to assist businesses in making better operational, tactical and strategic decisions. He gave a number of simple, yet valuable, tips on how analysts can get the most out of a client's data:

1. Set a clear goal, even if it is at a high level. This will ensure that the analysis undertaken has a clear direction.
2. Identify the project sponsor: someone who understands the business and the value of analytics, who will use the results of your analysis and take action in the business to bring about change.
3. Use ratios to see if there are interesting relationships in the data that the client may not be aware of. Compare the ratios over time and plot them on a map if it is geo-tagged. Exploring the data in this way will help you as the analyst to get a better understanding of the data.
4. Prioritise big and small-value items: for example, while using and analysing real-time truck tracking data may help you gain an understanding of truck driver behaviour, a high-level change in the planning process may allow the fleet size to shrink and thus result in greater savings. Therefore it's important not to get lost in all the data available.
5. Show results over time to identify patterns in the data. This is especially necessary when the client tends to compare their performance only to that of the previous week or the previous month. Sometimes it's necessary to look at the data over longer periods to recognise the trends. The period over which to study the data will differ from client to client. For one client, it may be necessary to look over a year long period, and for another it may be necessary to look over a five-year period.
6. Visualise the data in useful and appealing ways, as this is how you get people to notice the value of your analyses. Andrew and his team use Power BI² to visualise their data. Since it is an interactive tool, the client is able to play around with their own data to gain insights. Data are also continually fed into the dashboards, so it is not a static deliverable that becomes redundant one month after the client receives it.
7. Test the suggested solutions. Sometimes, the results from your analysis may be too far removed from the

I found the event a very good opportunity for networking and meeting people from the industry. For the next event, I would appreciate it if it was a bit more technical, and give us more information on the 'how'. I'd also like more info on where you get data for your projects. Overall it was very well organised.

- Neethu Mathew, ORSSA Johannesburg Chapter

client's current frame of reference. This may cause the client to be hesitant to implement your suggested solutions, but encourage them to implement the suggestion on a small scale to see if there are any improvements. Often the results speak louder than words.

[blind_faith_in_big_data_must_end](#)

²<https://powerbi.microsoft.com/en-us/>



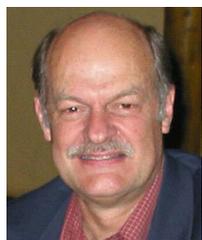
The ORSSA Pretoria Chapter is very grateful to Resolve Solution Partners for their willingness to make their facilities available to host our chapter events.

Overall, both talks were really interesting and gave attendees a glimpse into the life of a data scientist. ORSSA Pretoria and Jo'burg Chapter members should look out for future events in this seminar series. If you are a member of these chapters and did not receive the invitation to this event, please contact the database manager to ensure that your details are up to date.

¹https://www.ted.com/talks/cathy_o_neil_the_era_of_

BOOK REVIEW: OPTIMIZATION BY GRASP

Written by Hans W. Ittmann (hittmann01@gmail.com)



Hans Ittmann

Heuristics, or approximate algorithms, were introduced in the 1960s to find solutions, typically, to combinatorial optimization problems. Today a whole variety of heuristic methods and approaches are available. These methods are capable of handling larger problems, finding feasible solutions, usually faster than by exact methods, although they are not necessarily optimal. Metaheuristics on the other hand are general high-level procedures that coordinate simple heuristics and rules to find solutions to computationally difficult and complex optimization problems. Well known metaheuristics include genetic algorithms, tabu search, simulated annealing, variable neighbourhood search (VNS), and ant colony optimization. In 1989 Feo and Resende¹ introduced a new metaheuristic called Greedy Randomized Adaptive Search Procedure (GRASP). This was a probabilistic heuristic for solving hard set-covering problems.

Since being introduced GRASP has been used widely and successfully to address many different real-world combinatorial optimization problems. The main reasons for this success are that it has a strong intuitive appeal with an impeccable empirical track record whilst being fairly trivial to implement on parallel processors. GRASP typically consists of iterations made from successive constructions of a greedy randomized solution and subsequent iterative improvements of it through a local search. There are thus two phases associated with each of the GRASP iterations: (1) an initial solution is constructed via an adaptive randomized greedy function; and (2) a local search procedure is applied to the constructed solution in an effort to find an improvement. Optimization by GRASP is the first book dedicated to this metaheuristic method.

There are twelve chapters in total. At the end of each chap-

ter bibliographic notes, specific to the chapter, are given. Optimization is introduced in Chapter 1. The problems discussed here are classified into two classes: those with continuous variables and those with discrete variables. Most of the book is devoted to the latter and specifically to combinatorial optimization problems. Six typical and fundamental combinatorial problems are described and defined: the shortest path problem, the minimum spanning tree problem, the Steiner tree problem in graphs, the maximum clique problem, the knapsack problem and the travelling salesman problem. These are used throughout the book for illustrative purposes. Finally, exact and approximate solution methods are discussed in Chapter 1 which leads to an outline of heuristics and metaheuristics.

Chapter 2 introduces combinatorial optimization and for each of the six problem types the model formulation is presented with practical examples, graphically illustrated. The theory of computational complexity, the second main topic of this chapter, is then outlined in detail. This is again explained through the different problem examples. The concept of polynomial-time algorithms and non-polynomial-time algorithms are discussed and illustrated making ample use of examples. The notion of NP-hard problems is described as well as solution approaches which include heuristics and metaheuristics.

The two main phases that typify GRASP, construction and local search, are dealt with in the next two chapters. The construction of feasible solutions via greedy algorithms is outlined step-by-step with ample use of pseudo code and examples. Adaptive greedy and semi-greedy algorithms are touched on as well as repair procedures. It is shown that local search methods start from any feasible solution and different techniques and ways of determining other solutions are discussed in detail. Neighbourhood search, illustrated with search space graphs, is explained using examples

while implementation strategies are outlined as well. In the end it is shown that a great number of feasible solutions are visited until one is found that cannot be improved further. The various methods are described in depth.

With the necessary theory and background covered in the introductory chapters, Chapter 5 introduces the basic structure of GRASP as a semi-greedy multi-start procedure with local search. Random multi-start as well as semi-greedy multi-start algorithms are outlined and this leads to a description of the basic GRASP heuristic. Again, ample use is made of examples to illustrate how these algorithms, methods and procedures work. Ways of accelerating GRASP with stopping rules including probabilistic stopping rules are presented. There is a short section on how to solve multiple objective minimization problems using GRASP.

Chapter 6 presents ways of determining how well the heuristic performs using runtime distributions. The objective is to show how well the heuristic is performing both in terms of running time and proximity to a given target value. Comparisons with other algorithms are also made. The runtime distribution methodology is used to evaluate and compare parallel implementation of stochastic local search algorithms.

A whole variety of extensions, enhancements and variants of GRASP is considered in Chapter 7. The fundamentals of part-relinking are introduced in Chapter 8 and all the different implementation issues and strategies are described in detail. Path-relinking as it relates to the basic GRASP heuristic is outlined in Chapter 9. Here consideration is given to variants of the basic scheme, evolutionary path-relinking and also restart strategies in the case of part-relinking for GRASP.

The implementation of GRASP on parallel computers is described in Chapter 10. Typically this is done by partitioning the search space for the iterations, and then assigning each partition to a processor. The two main approaches to parallelization namely multiple-walk independent-thread or the cooperative-walk independent-thread are discussed. The implementation of the parallel GRASP heuristic for three

examples is given. The problem types are the three index assignment problem, the job shop scheduling problem and the 2-path network design problem.

The GRASP heuristic can also be extended to address continuous box-constrained global optimization problems and this is the topic of Chapter 11. Like the discrete GRASP heuristic the continuous GRASP, or C-GRASP, heuristic also has two phases. In the construction phase a greedy randomized solution is constructed while during the local search phase a local search algorithm leads to an approximate local optimal solution. A deterministic rule triggers a restart search after each of the iterations.

In the final chapter four case studies are presented that illustrate use of the GRASP heuristic. The focus is on how to customize the method for each case. The four problem types are the 2-path network design problem, graph

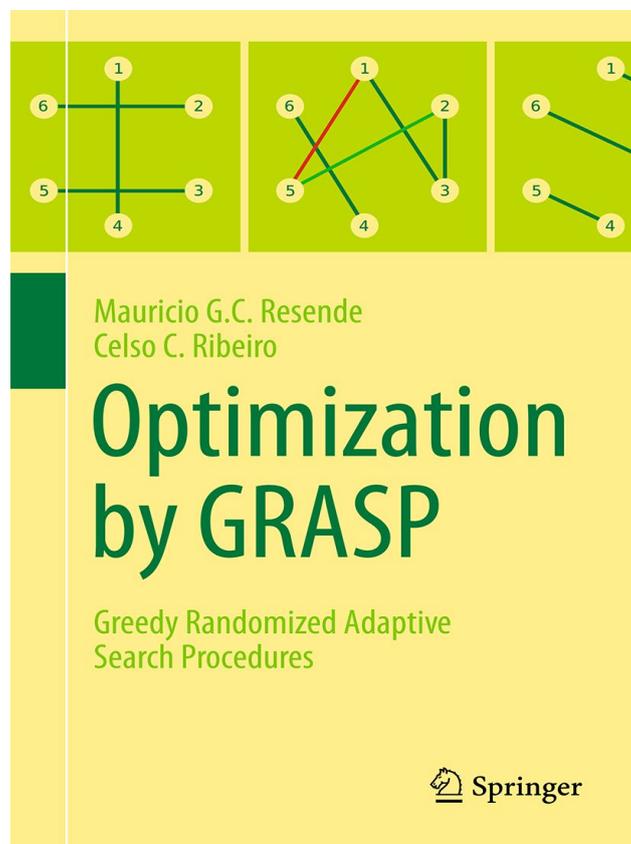
planarization, unsplittable multicommodity flows and maximum cut in a graph. Each step is clearly described, in particular the construction and local search procedure. Path-relinking is covered and illustrated in a number of these case studies while a parallel GRASP is briefly touched on.

Optimization by GRASP is a well-structured and well written introduction to GRASP. In addition it is very suitable for and highly accessible to students, researchers and practitioners who want to familiarize themselves with combinatorial optimization and greedy algorithms. The same holds true for those wanting exposure to heuristics and metaheuristics and how these methods are

structured. The book provides an excellent overview of GRASP and will appeal to researchers and practitioners of combinatorial optimization.

¹T. A. Feo and M. G. C. Resende, A Probabilistic Heuristic for a Computationally Difficult Set Covering Problem. *Operations Research Letters*, 8:67-71, 1989.

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OR Anecdotes: The birth of OR during WWII

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World War II became known as the 'wizard war' because of the continuous cycles of counter-counter measures employed by both the German and allied commands. Through Operational Research (OR) – the scientific scrutiny of new weapons, their deployment and relative efficiency influenced how warfare itself was conducted.

Scientists in the United Kingdom including Patrick Blackett, C. H. Waddington, Owen Wansbrough-Jones, Frank Yates and Cecil Gordon and in the United States George Dantzig, looked for ways to make better decisions in such areas as logistics, training schedules and large scale war strategy. A number of crucial analyses were made in the course of the war which aided the allied war effort tremendously [1].

Britain introduced the convoy system to reduce merchant shipping losses in the Atlantic, but while the principle of using warships to accompany merchant ships was generally accepted, it was unclear whether it was better for convoys to be small or large. It was noted that small convoys could travel faster, and would also be more difficult for German U-boats to detect, but on the other hand, large convoys could deploy more warships against an attacker, and defend themselves more effectively. A typical trade-off scenario was encountered where the convoy size and composition needed to be optimised. The conclusion, after careful analysis, was that a few large convoys are more defensible than many small ones, and Blackett's team made recommendations to the Admiralty which were implemented successfully [2].



Merchant ships sailed in 'convoys' for safety, accompanied by warships.

In another piece of work, Blackett's team analysed a survey carried out by RAF Bomber Command. For the survey, Bomber Command inspected all bombers returning from bombing raids over Germany over a particular period. All damage inflicted by German air defenses was noted and the recommendation was given that armour be added in the most heavily damaged areas.

Blackett's team disagreed with the survey and instead made the surprising and counter-intuitive recommendation that armour be placed in the areas which were completely untouched by damage. They reasoned that the survey was biased, since it only included aircraft that successfully came back from Germany. The untouched areas were probably vital areas, which, if hit, would result in the loss of the aircraft.



B-25 Mitchell bomber

When the Germans organised their air defences into the Kammhuber Line [3], it was realised through the work of Blackett's team that if the RAF bombers were to fly in a bomber stream they could overwhelm the night fighters who flew in individual cells directed to their targets by ground controllers, who used the stacked radars in the Kammhuber line to direct them. It was then a matter of calculating the statistical loss from collisions against the statistical loss from night fighters to calculate how close the bombers should fly to minimise RAF losses [4].

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