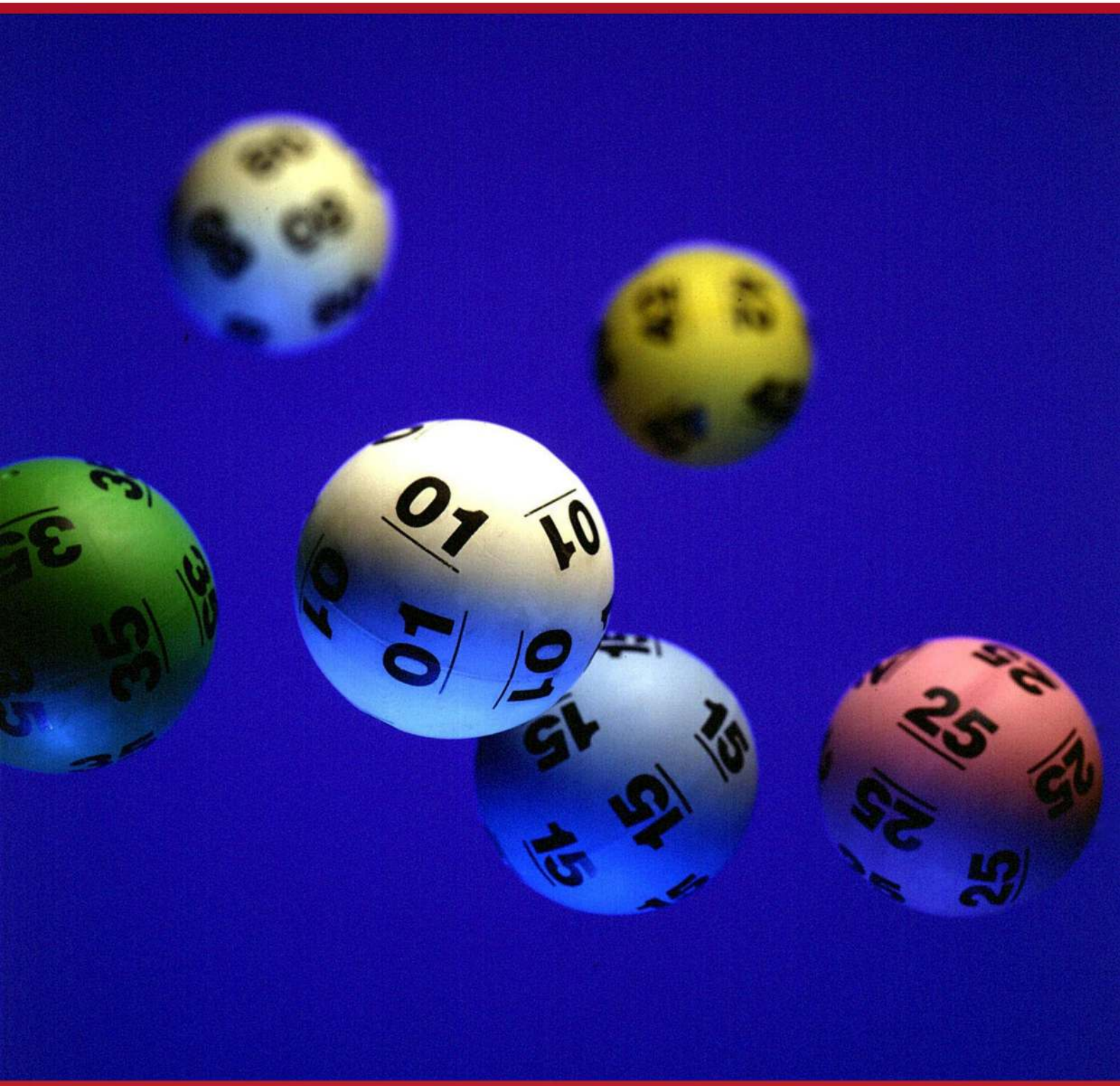
Newsletter

Operations Research Society of South Africa
Operasionele Navorsingsvereniging van Suid-Afrika



December 2009
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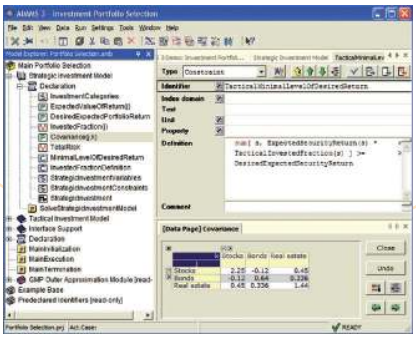
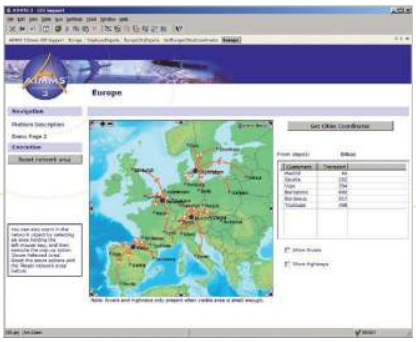


Transparent model formulation



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FROM THE EDITOR

Contactable at: zane@sun.ac.za

Zane Simpson

This is unfortunately the last newsletter for which I am editor, and I just want to begin by saying I have really enjoyed being the editor.

To end of with a "bang", I have put together a newsletter which I hope you find to be an enjoyable read.

We start off with *Off the President's Desk* by Prof Sarma Yadavalli, followed by an obituary of Prof J Dewald Roode, who played a significant role in ORSSA during the early years. Our member profile for this issue is Prof Maseka Lesaoana, from Limpopo University, who is the organiser of the ORSSA 2010 conference.

The article for this newsletter is a very interesting one, on the national *Lotto*. I am more than sure you will all find it very interesting, especially if you have wondered about your chances of winning, or been included in a typical conversation about it.

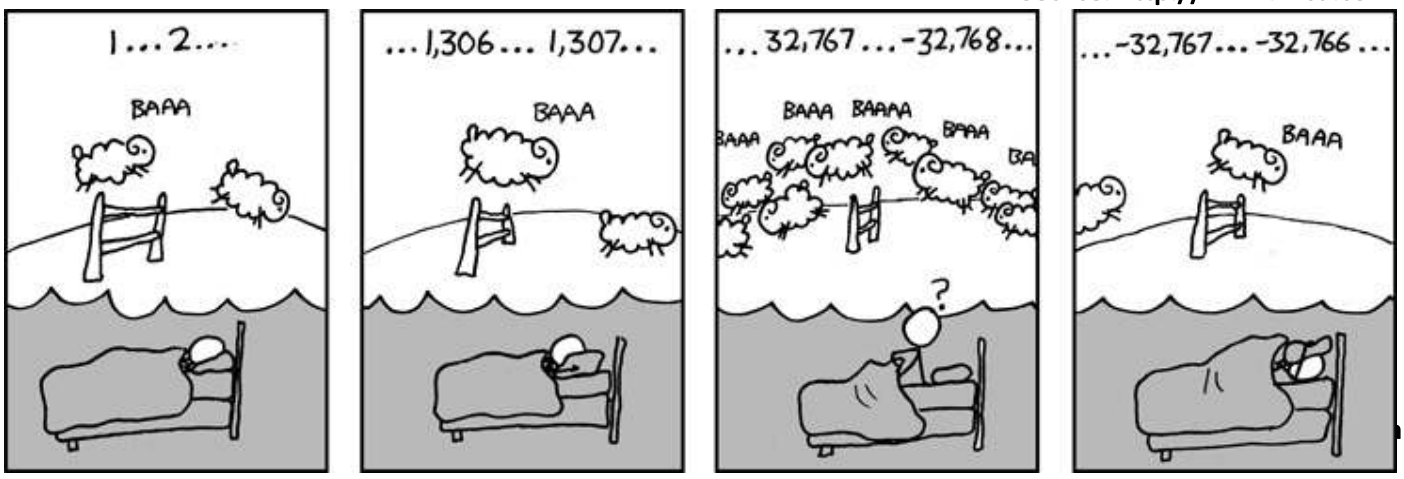
I hope you all have a great end of year holiday and Christmas, and lastly… Thank you to all those of you who have assited me with the newsletter, and those who have provided inputs. It has all been very much appreciated.

Finally, I would like to wish the next newsletter editor, Danie Lötter, all the best. Please support him with interesting newsletter material as you have supported me over the past year.

Features

COMIC

Source: http://www.xkcd.com



FROM THE PRESIDENT'S DESK

by Sarma Yadavalli (yadavalli@postino.up.ac.za)
ORSSA President

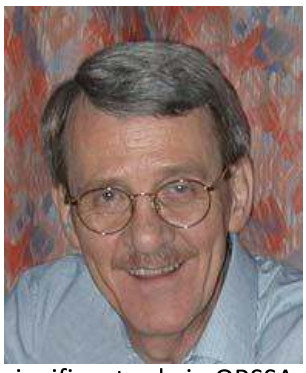
I feel greatly privileged to have the opportunity to serve ORSSA as its President and wish to thank you all for your support. We just have celebrated the 40th birthday of ORSSA in September at Stellenbosch. In a short span, our Society has grown in an encouraging manner with nearly 300 members, thanks to the vision of our founder Presidents and the efforts of the office bearers and members of the executive. I solicit your suggestions to enhance activities of ORSSA and to reach out to many more in our fraternity, particularly the young ones.

During the last ORSSA annual conference at Stellenbosch, a session was devoted to Equity, Poverty Alleviation & Humanitarian OR which is extremely important for the Government and the industry. Such sessions should be planned for the next ORSSA conference so that the participation from all sections will be high.

Every year our Society recognizes individuals for their contributions to Operations Research. This year too, four operations researchers have selected for the awards of the Society (Gideon de Wet, Jan van Vuuren, Marthi Harmse and Theo Stylianides) have been conferred the awards. I wish them all further success and luck in their research endeavours.

I very much look forward to seeing you all at the 39th annual conference in Limpopo Province in September 2010. In the meanwhile, I hope many new Operations Researchers will become members of our Society so that we can become a strong fraternity. ORSSA will be looking forward to your support and new ideas.

OBITUARY – PROF J DEWALD ROODE



Dewald Roode passed away on Sunday morning 27 September 2009 after a very long struggle with cancer. It is with sadness that we as an OR community took note of his passing. He was one of the founding members of ORSSA and played a significant role in ORSSA during the early years.

Dewald Roode was born in 1940 and obtained a masters degree in theoretical physics and a master's degree in mathematics from the University of Potchefstroom in South Africa. He then obtained a PhD at the University of Leiden in the Netherlands in 1968. The title of his PhD was "*Generalized Lagrangian functions in mathematical programming*" - a very strong OR oriented topic and his promoter was the well known Dutch professor, Prof Zoutendijk. His first position was as a scientist at the South African Atomic Energy Board, where he was responsible for scientific programming.

Professor Dewald Roode pioneered the field of Information Systems in the Southern Hemisphere through transferring his extensive knowledge to a host of academics at various universities in South Africa.

Prof Roode's academic career started in 1971 as a professor of computer science, at the then Rand Afrikaans University in Johannesburg. In 1981 Prof Roode became the first Director of the South African Computer Users Council (CUC) (1981 to 1983), and was responsible for coordinating the development of standards for training in the South African computer industry. Following that Prof Roode spent several years involved in and managing a large number of consultancy projects for major South African firms.

In 1988 he was recruited to head the new Department of Informatics at the University of Pretoria, while continuing on a part-time basis with consultancy work. In 1995 Prof Roode was requested by the University of Pretoria management to accept, in conjunction with his job as Head of the Department of Informatics, the job as Director of Information Technology (responsible for all computer and network services to the entire university). He handled these two positions

concurrently until 1998, when a new academic dispensation was established with the creation of the School of Information Technology, incorporating the three academic departments of Computer Science, Informatics and Information Science. Prof Roode became its first Director in March 1998.

At the end of 2001 Prof Roode decided to continue with academic work at different universities, and to devote more time to high-level training of individuals in the computer industry who had not had the opportunity to receive formal tertiary education. This decision meant that he had to exercise an early retirement option at the University of Pretoria. In 2002, Prof Roode was appointed to be Professor Emeritus and Professor Extraordinary in the Department of Informatics of the University of Pretoria.

Since 2003, Prof Roode was also Visiting Professor in the Department of Information Systems of the University of Cape Town, and was instrumental in strengthening the PhD programme and mentoring new PhD supervisors. He was appointed Honorary Professor in the Faculty of Business Informatics of the Cape University of Technology in 2004. In addition to all of this he was also involved in presenting seminars for the Council for Scientific and Industrial Research (CSIR).

A very important focus of Prof Roode's academic career was supervision of doctoral students. In all, Prof Roode mentored more than 30 doctoral students from across several South African universities, empowering them to supervise their own students. These included students from Cape Peninsula University of Technology, Nelson Mandela Metropolitan University, Potchefstroom University, University of Cape Town and University of Pretoria.

In 1996 Prof Roode became a member of Working Group 9.4 of the International Federation for Information Processing (IFIP). In 1999 he was appointed as South Africa's representative on IFIP's Technical Committee 8 on Information Systems. Prof Roode was elected as Vice-Chair of TC8 in 2000, and as Chair in 2001, for the period 2002 – 2004. In 2004 he was re-elected as Chair for the period 2005 – 2007.

Prof Roode was also involved in IFIP's World Information Technology Forum (WITFOR) and was a member of the Steering Committee of the first WITFOR event in 2003 in Vilnius, Lithuania, and Program Chair of the second WITFOR in 2005 in Gaborone, Botswana. In 2007 Prof Dewald Roode was honoured by IFIP with the Silver Core award, the highest accolade for service.

Prof Roode also achieved world-wide honour in 2008 with the LEO Lifetime Achievement Award. Named after one of the world's first commercial applications of computing (The Lyons Electronic Office), the purpose of the LEO Award is to recognize truly outstanding individuals in the Information Systems community. It is awarded to truly outstanding scholars or practitioners who have made exceptional global contributions in the field of Information Systems. Winners are regarded as a pre-eminent representatives of their national or regional Information Systems communities.

The next two paragraphs indicate his involvement in the early years of ORSSA (Geldenhuys *et al* - A Brief History of the Beginnings of Operations Research in South Africa). "Another important development in the sixties was that a number of young operations researchers returned from studies overseas where they had training in OR at distinguished universities, to the benefit of their respective fields of employment in South Africa. Amongst them were D.D. (Dave) Masterson in the banking sector, H.J. (Hennie) Venter at the University of Potchefstroom, R.J. (Roelf) van den Heever at the University of Pretoria, J. Dewald Roode at the Atomic Energy Board, Gideon J.J. van Zyl at the University of Stellenbosch and later at the University of Port Elizabeth, and N.J. (Nic) Breytenbach at the University of South Africa. Prof. Venter was the supervisor for several Ph.D. students in OR topics, amongst others J.M. (Giel) Hattingh in quadratic programming and M.J. (Maarten) Venter in inventory control.

A new Pretoria Chapter was founded on 19 March 1970, with the following executive committee: Dr. J.D. Roode (Chairman), Dr. R.J. van den Heever (Vice-Chairman), G. de V. de Kock (Secretary), A.P.L. Kotze (Treasurer) and A. Haller (Additional Member)."

Dewald was therefore the first chairperson of the Pretoria Chapter of ORSSA. One of his other major contributions to ORSSA was the design of the ORSSA logo which he did together with Dr Maarten Venter. Although his interests shifted to IT he will be sorely missed by the OR community in South Africa. A truly outstanding individual and academic!

MEMBER INTERVIEW: MASEKA LESAOANA

Contactable at: masekal@ul.ac.za

Maseka Lesaoana

Maseka was born in Lesotho, where she obtained her basic education. Her passion for numbers started in the family, sparked by her "uneducated" parents who owned a local business in the most rural part of Lesotho, and eventually landed her as a mathematics teacher at a secondary school immediately upon completion of her COSC (Cambridge Overseas School Certificate) – which is an equivalent of a matric certificate in the South African context. After one year as a school teacher, she joined the Bureau of Statistics in Maseru, Lesotho, and two years later (1977) she was awarded a Lesotho Government Scholarship to pursue a two-year Certificate in Statistics at the National University of Lesotho (on study leave). With a distinction at the end of the certificate programme she proceeded with the remaining two years to complete a BA degree in Statistics and Economics, with a bias towards the former.

You are a relatively new member of ORSSA. How did you become involved in operations research and specifically with ORSSA?

The Department of Statistics at the National University of Lesotho (NUL) where I pursued my undergraduate studies has elective courses in Operations Research (OR). This is where I got to know about the field, and where my love for OR emerged. As a third and fourth year student at NUL, I was a tutor for first and second year students, respectively. Such tutorship was closely monitored, and I became one of the two students in the 1981 cohort of graduates earmarked for further training by the University.

Upon completion of my first degree, I was employed by NUL as a teaching assistant (junior lecturer). A year later I was awarded a Canadian International Development Agency (CIDA) scholarship to pursue a Masters degree by course work at the University of Waterloo, Ontario, where I studied Statistics as well as Combinatorics and Optimization. My master's essay was on linear programming under the guidance of Prof Michael Best. I obtained the degree Master of Mathematics (Combinatorics and Optimization) in 1985, while on study leave at NUL.

Back to NUL in 1985, I rejoined the Department of Statistics, as a lecturer – teaching both Statistics and Operations Research. In 1988 I was awarded the United Nations Development Programme (UNDP) sponsorship that enabled me to pursue PhD at the University of Southampton, UK – under the supervision of Dr Chris Potts, who has published widely in Scheduling Theory. My interest in Operations Research grew, and I had an opportunity to present papers in my field of study in France and the Netherlands, while a PhD student in the UK. My thesis is entitled *Scheduling with Fixed Delivery Dates*.

On completion of my PhD in 1991, I went back to NUL as Head of the Department of Statistics, where I taught both Statistics and Operations Research. Sadly, I left academia in January 1994 to join the Human Sciences Research Council (HSRC) in Pretoria as Head of the South African Data Archive, where I spent six years before moving to the National Department of Labour, as Director of Labour Market Information and Statistics. During the ten-year break from academia I worked on the publication of an article from my PhD thesis in collaboration with Chris Potts and Nicholas Hall, (Operations Research, Vol. 49. No. 1 (Jan. – Feb., 2001), pp 134-144).

It is only four years since I have become a member of ORSSA. I find networking among operations researchers in South Africa, and Africa as a continent rather difficult, mainly due to a limited number of those in the field. This became evident at the IFORS Conference that took place at Sandton in 2008, where participants from the Western world dominated.

How, in your opinion, can ORSSA become more effectively involved in promoting the use of OR techniques towards development and poverty alleviation in South Africa?

The origins of OR can be traced back to World War II when George Dantzig developed the powerful simplex method for solving linear programming problems, for which OR techniques devised powerful mathematical models that came up with the best solutions under

scarce resources. Poverty, rural development and the young democratic South Africa are in a similar situation. OR practitioners need to be more proactive by finding inroads in undertaking evidence-based research using OR techniques, and capacity building among young operations researchers. The main challenge remains that of marketing OR and attracting students into the field. OR is virtually unknown in Africa, to the extent that most activities addressing African problems that require OR techniques tend to be driven by the Western World. For example, in 2008, Operations Research Practice (ORPA 4) with the theme "Using Operations Research to address Urban Transport and Water Resource Management Issues in Africa" was hosted by Louisana Technical University, in USA. This is one good area that shows the role OR can play in development. Similarly, OR techniques can be used towards development, poverty alleviation, HIV/AIDS problems, unemployment, infrastructure development, and manpower planning in general, in South Africa and on the Africa continent. The infancy of OR as a field in Africa, requires us to build strong networking relationships with experts nationally, regionally and globally. In this way we can be able to produce a reasonable number of graduates in the field. The marketing of OR needs to start at school level.

By using OR techniques both the private and public sectors will realize notable improvements such as higher revenue, lower cost, increased market share, reduced risk, greater productivity, faster turnaround and more efficient use of limited resources which will ultimately improve the entire economy. We need to create a database of OR practitioners and academics in South Africa, such as NOREA which was created in 2007 after the ORPA/ORSSA conference. We need to build Research Collaboration with other national, regional and international universities, as well as Industry.

It has been mentioned that there is interest in establishing a new Limpopo Chapter of ORSSA. Is this true? Can you enlighten readers about your vision for such a chapter, if it were to come into being, as well as your possible involvement in its establishment?

When I joined the Department of Statistics and Operations Research (STOR) at the now University of Limpopo in 2003, I was the only one with Operations Research skills. Furthermore, STOR, like all other departments in the School of Computational and Mathematical Sciences, operates with a merger number of staff, mainly at a junior level. Being lumped with statistics, the first preference in terms of courses offered under such conditions goes to statistics, with its long history as a field. However, I managed to graduate one student with an MSc, only this year (2009). The inclusion of staff members from the National University of Science and Technology (NUST) in Zimbabwe has been an added advantage to the development of OR at the University of Limpopo (UL). The high attrition rate among staff at UL makes it difficult to make a break-through in the development of OR. We may need to first develop our "permanent" staff to higher post-graduate levels before launching a sustainable ORSSA Chapter. However, our hosting of the 2010 ORSSA Conference could be a strong case for such a Chapter. It should also be noted that there are two universities in the Limpopo Province: University of Limpopo and University of Venda. The latter does not offer Operations Research courses.

You are the organiser of the ORSSA 2010 Conference. Can you tell us more about your plans, including the venue, the conference theme and where readers can find out more information on the conference?

It is now official that the University of Limpopo will be hosting the ORSSA 2010 Conference, at Limpopo's Magobaeskloof Hotel, which is located some 40km to the east of the University's Turfloop Campus. We are ecstatic about this development and the support we received from ORSSA members nationally and beyond. The Main Conference is scheduled for 26 – 29 September 2010.

Already, we have been to Magoebaskloof Hotel three times, and have established a local organizing committee. Magoebaskloof is a very spectacular venue. I extract the following from their website: "*A warm welcome awaits visitors to this mountain haven. Set in the dramatically beautiful Magoebaskloof area of Limpopo, the hotel offers guests a chance to enjoy an idyllic and relaxing break in the country. Friendly personal service and comfortable accommodation are a hallmark of the hotel. It is an ideal venue to explore this fascinating region*", (www.magoebaskloof.co.za).

This is surely not a place to miss! This is where we can launch a sustainable ORSSA Limpopo Chapter.

I invite all members and non-members with interest in OR to participate. While the success of the Conference as measured by the quality of papers and discussion will be the key indicator of success, there are quite a number of other entertainments outside the Conference Programme, including Kruger National Park that is just of one hour drive from Magoebaskloof.

What do you think ORSSA is doing well? And where do you think ORSSA can improve in terms of its current activities?

ORSSA holds national annual conferences, and this should be continued. ORSSA also has a well informative website, and visitation of this website needs to be marketed well. ORSSA also encourages students' competitions. However, ORSSA needs to jump out of the old practices and build strong networking relationships among all institutions in the country. The 2010 Conference that will be hosted by the University of Limpopo is a step in the right direction since this will be the first ORSSA Conference to be hosted by a previously disadvantaged university.

There are however, a number of areas that may need improvement. These include (a) the involvement of all stakeholders, i.e. private sector, academics and the public sector - there is a lot that OR can offer to industry and government departments; (b) involving other countries in the SADC region. This can eventually lead to the formation of a Southern African Operations Research Society; working closely with other African OR societies such as Operations Research Practice in Africa (ORPA), The Africa OR Network (AORN), The Operational Research Society of Morocco, The Operations Research Society of East Africa (ORSEA), The West and Central African Network of Operational Research (WACANOR); (d) Currently ORSSA is not well represented (academics, practioners, public, NGOs, and private sector). This anomally needs to be addressed; (e) ORSSA has been in existence since 1969 but still its not popular. We need to address this; and (f) One of the reasons why OR presents untapped opportunities is that the field frequently is invisible or if visible, misunderstood. We have to make it visible by marketing ourselves and carry out meaningful research.

You were head of the Department of Operations Research and Statistics at the University of Limpopo. Can you tell us more about the undergraduate and postgraduate OR programmes offered by your department?

In 2003, my interest in academia landed me with the Department of Statistics and Operations Research at the then University of the North which became University of Limpopo in 2005 (a merger with Medunsa). The Department of Statistics and Operations Research (STOR) at the University of Limpopo is one of the three departments in the School of Computational and Mathematical Sciences, in the Faculty of Science and Agriculture, the other two departments being Computer Science and Mathematics & Applied Mathematics. I have been acting as Director of the School since January 2009. I was Head of the Department of Statistics and Operations Research in 2004-2005.

The undergraduate programme in OR is slowly attracting students. When I joined the University in 2003 there were only 3 students, and currently there are nearly 20 students. With the merger with Medunsa, OR is also expanding in that direction, albeit under a shortage of staff.

What is your message to young and aspiring operations researchers?

OR is a fairly new field in institutions of higher learning on the African continent. In most SADC universities it appears as a sub-programme under the Department of Statistics. This often leads to a misunderstanding that OR is a branch of statistics. The interdisciplinary nature of OR makes it attractive to most academics and researchers who get to know about it. OR techniques are mainly published in Operations Research as well as Management Science books and journals. As an interdisciplinary field, applications of OR techniques are often found in mathematics and applied mathematics, statistics, computer science, industrial engineering, business and economics.

OR offers a lot of opportunities, and a wide variety of applications. The major quantitative techniques covered are optimization, simulation, probability and statistics, which make it richer than most mathematical fields. The advent of computer technology is an added advantage to OR.

Maximising customer knowledge to accelerate profitability in financial services

By Percy Thaver, Industry Executive: Financial Services at SAS South Africa

Financial services organisations face many challenges that are constantly evolving as the business world changes. IT such as predictive analytics is often embraced to address these challenges. Historically, however, these tools have been used in a stopgap manner and individual projects have failed to improve overall enterprise efficiency.

By focusing on an enterprise-wide approach, financial services organisations can achieve better long-term cost savings, revenue growth and profitability – regardless of the new challenge waiting around the corner.

Facing new challenges

Consolidation, revenue generation and customer loyalty are addressed by predictive analytics in the form of customer segmentation and retention. Financial services companies are now among the largest and most mature users of predictive analytics for this purpose.

However they now have to address other challenges like channel options, as customers increasingly can choose how they want to interact. So while efforts may have been made to maximise the success of one channel, today that same focus needs to apply to ensuring a successful customer experience integrated across all channels.

Another major challenge is profitability. The focus on bottom-line growth will never relent, and firms need to secure the loyalty and increase the profitability of those clients.

Predictive analytics is the answer

Predictive analytic technology can address these issues by giving customers smart, appropriate interactions regardless of which channels they use.

To accomplish this and also increase customer profitability, organisations need to create appropriate, personalised intelligence about individuals and ensure that detailed knowledge is available and used across the company. Predictive analytics allows the sharing of information throughout organisations.

Companies can turn employees into knowledge workers by expanding access to predictive, analytic-based customer insight across the enterprise, and embedding predictive analytics into business processes, allowing tracking and response to customers with a consistent message across all touch points.

Improved cross-selling

Efficient cross-selling requires appropriate timing of interactions from the customer's perspective. The problem is to determine the most appropriate time. Trigger-based marketing uses alert systems that identify suitable cross-sell opportunities based on changes in an individual customer's behaviour.

However, offering the right product at the right price and time is not always enough. Trigger marketing should work hand-in-hand with other analytic systems, aligning the message and channel most likely to be successful.

More profitable cross-selling

Traditional cross-selling techniques are relatively ineffective for increasing revenue, increasing the volume of products sold, not the profit. The end result is cannibalisation or unprofitable use of a product, as opposed to wallet-share increase or balance sheet growth.

Effective cross-selling depends on analysing detailed information about customers, focusing on appropriate products. By basing decisions on facts, not guesses, firms can increase cross-sales effectiveness and profitability.

Percy Thaver, Industry Executive: Financial Services at SAS South Africa

To End

Predictive analytics is delivering tangible results to financial services firms, and use of this technique to serve individual product lines and lines of business has grown tremendously.

Moving forward, the focus will be on extending its use across the enterprise, resulting in a company-wide, in-depth knowledge of customers and an integrated, proven approach to maximising customer satisfaction and profitable cross-selling.

To learn more about how to meet the requirements for real-time decision making, contact SAS on +27 11 713 3400 (Johannesburg and Tshwane) or +27 21 912 2420 (Cape Town) or visit our website, www.sas.com/sa

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How many players can win the South African national lottery before raising fears of irregularities?

by Alewyn Burger, André du Plessis*, Sarel Steel† and Jan van Vuuren**
***Department of Logistics, University of Stellenbosch**
†Department of Statistics and Actuarial Science, University of Stellenbosch

On Saturday night 7th February 2009 an unlikely event occurred: an unbelievable eighteen (out of approximately 7.5 million) players won the jackpot in the South African national lottery, *Lotto* – the winning numbers on that night were $3, 13, 17, 28, 37, 49$ with bonus number 30 [1]. This prompted a letter by D Gilfillan of Table View to the Editor of the Cape Argus, which appeared in print on Monday 16th February 2009, in which he wrote "There is a scam going on in the *Lotto*. Any statistician will confirm that the possibility of 18 identical selections of six numbers out of 49 is so low as to be 'almost' impossible …" and continued with the following call: "An investigation is required …" [2]. In a subsequent letter to the Editor of the Sunday Independent, which appeared in print on Sunday 1st March 2009, the media liaison of the National Lotteries Board (NLB) in Pretoria, ST Naidoo, responded that there is "…nothing fishy about multiple *Lotto* winners" [3]. Naidoo presented a careful overview of the regulatory processes followed to ensure the integrity of the game. While it is almost certain that Gilfillan was calling for a forensic investigation, the present authors were inspired to attempt a statistical investigation into the probability of multiple players winning the jackpot.

Under the important assumptions that

(i) each *Lotto* player plays a single ticket whose six numbers are drawn randomly according to a uniform distribution from the universal set $\{1, \ldots, 49\}$ and

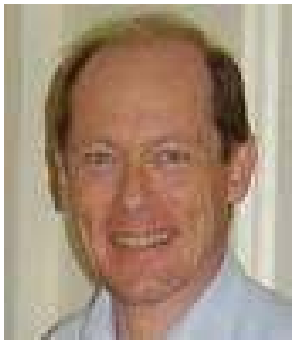
(ii) the six winning *Lotto* numbers are also drawn randomly according to a uniform distribution from the same universal set,

it follows by the probability mass function of a binomial random variable that the probability of m players sharing the jackpot is $P(N, m) = \binom{N}{m} p^m (1-p)^{N-m}$ if N players participate in the game, where p denotes the probability of a single player guessing the six winning numbers correctly, i.e. $p = 1/\binom{49}{6} \approx 7.15112 \times 10^{-8}$. It is not easy to compute the value of $P(N, m)$ for large values of N, because of the large numbers involved in the binomial coefficient and in the second exponent. However, for large values of N this probability may be approximated particularly well by the Poisson probability mass function $P'(N, m) = e^{-Np}(Np)^m/m!$ in view of the small value of p, as shown in Table 1 for various values of N and m.

From the shaded probability $P(7\,500\,000, 18) = 1.23189 \times 10^{-21}$ in Table 1 it would seem that

*Alewyn Burger**

*André du Plessis**



Sarel Steel†

*Jan van Vuuren**

$P'(N,n)$	$N = 5\,000\,000$	$N = 7\,500\,000$	$N = 10\,000\,000$	$N = 12\,500\,000$	$N = 15\,000\,000$
$m = 1$	2.50069×10^{-1}	3.13696×10^{-1}	3.49788×10^{-1}	3.65656×10^{-1}	3.66954×10^{-1}
$m = 5$	3.40609×10^{-5}	2.16306×10^{-4}	7.62291×10^{-4}	1.94549×10^{-3}	4.04848×10^{-3}
$m = 10$	6.58257×10^{-12}	3.17443×10^{-10}	4.71423×10^{-9}	3.67171×10^{-8}	1.90125×10^{-7}
$m = 15$	1.06753×10^{-19}	3.90937×10^{-17}	2.44650×10^{-15}	5.81505×10^{-14}	7.49255×10^{-13}
$m = 18$	9.96717×10^{-25}	1.23189×10^{-21}	1.82737×10^{-19}	8.48330×10^{-18}	1.88880×10^{-16}

Table 1: Approximations of the probability $P(N,m)$ of m players sharing the jackpot if a total of N players participate in the game.

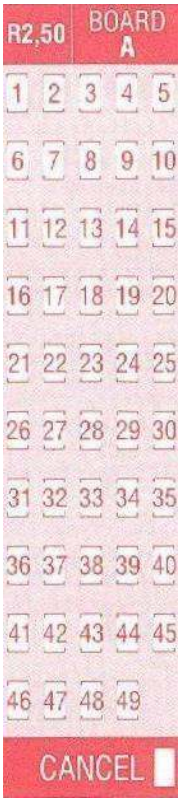
Gilfillan's allegation of statistical almost-impossibility of 18 winners winning the jackpot on 7th February 2009, based purely on an interpretation of the values in Table 1, may be well founded. This probability is so small that, if it is assumed that 104 draws take place per year, one may expect to wait approximately $7.805\,39 \times 10^{18}$ years (more than a million times the estimated age of the known universe) for an event as rare as this to occur. Perhaps a more intuitive approach towards corroborating this result is to consider the set of all $\binom{49}{6} = 13\,983\,816$ possible tickets that may be selected and to ask how many of these tickets are expected to be played m times if N players were to participate in the game – denote the answer to this question by $E(N,m)$. Values of $E(N,m)$ may be approximated by means of a Monte Carlo simulation and are shown in Table 2 for various values of N and m.

It is clear, from Table 2, that no ticket is expected to be played even 10 times if a total of 7.5 million tickets are selected – let alone 18 times! How, then, should one make sense of the occurrence of 18 jackpot winners on 7th February 2009 in view of the extremely small probabilities in Table 1 and the zero values in Table 2? In fact, similarly natured events occurred on 31st October 2001, when 19 players shared the jackpot, and on 15th March 2003, when the arithmetic sequence $23, 25, 27, 29, 31, 33$ rolled out as winning numbers … on that night an astonishing 33 players won the jackpot, each receiving R111 901 [1]. It would seem that the waiting times between these extreme events of large numbers of jackpot winners resembles nothing like the expected waiting time of more than a million times the age of the known universe! The nature of the winning ticket on 15th March 2003 hints towards a possible explanation of this puzzling contradiction …

$E(N,m)$	$N = 5\,000\,000$	$N = 7\,500\,000$	$N = 10\,000\,000$	$N = 15\,000\,000$	$N = 20\,000\,000$
$m = 1$	3 496 843	4 386 647	4 891 435	5 131 369	4 785 090
$m = 2$	625 205	1 176 339	1 748 916	2 752 119	3 421 809
$m = 3$	74 510	210 329	416 899	984 095	1 631 407
$m = 4$	6 662	28 199	74 521	263 886	583 289
$m = 5$	478	3 023	10 663	56 607	166 847
$m = 10$	0	0	0	3	33
$m = 15$	0	0	0	0	0
$m = 18$	0	0	0	0	0

Table 2: The expected number, $E(N,m)$, of tickets played m times if N players were to participate in the game. These values were obtained from a Monte Carlo simulation ($1\,000$ iterations). It was assumed that all numbers drawn are random according to a uniform distribution, and that all numbers selected by participants are also random according to a uniform distribution.

An answer to this riddle lies in the realisation that our assumption (i) above may be flawed – in other words, that *Lotto* players might not select their six numbers according to a uniform distribution after all! While Haigh [4] found no evidence that the winning numbers of the United Kingdom National Lottery[1] are not uniformly distributed, there is indeed evidence to suggest that players use their birthdays, the birthdays of celebrities, scores in sports games, current events and the geometric properties of the arrangement of the 49 numbers on the tickets they fill in to choose their numbers [5, 6]. It is perhaps natural to attempt to "spread out" the numbers one chooses when participating in the lottery in the (false) hope of increasing one's chances of covering a larger portion of the winning numbers, and the rectangular grid arrangement of numbers on *Lotto* tickets (shown on the right) may prompt the nature of spread that players employ. One method which may be used is the construction of tickets containing numbers which form an arithmetic sequence, as was the winning ticket on the night of 15th March 2003. The number choices in these tickets either arise from a purposeful selection of an arithmetic sequence by the participant, or by a selection of numbers which form some sort of geometric pattern on the physical lottery ticket. To understand this, consider the physical layout of a lottery ticket. Some participants may decide to play the numbers in a specific row, column or diagonal. If a participant were to select ticket numbers in this way, then the participant's playing ticket numbers form an arithmetic sequence. For example, if the participant chooses the numbers in the middle column, from the top, the ticket $(3, 8, 13, 18, 23, 28)$ results. This is an arithmetic sequence in which the difference between any two numbers is *exactly* 5. An extension of this idea is if participants purchase tickets in which the difference between any two numbers in the ticket is *at least* some number k. Tickets of this form may arise when a participant plays the numbers in a diagonal of the ticket, together with another number, such as $(15, 19, 23, 27, 31, 49)$. This raises the following question: How would our analysis above be altered under the alternative assumption that



(iii) some proportion, θ, of *Lotto* players choose their six numbers ensuring some kind of spread between the numbers, but that the remaining proportion, $1-\theta$, select their numbers according to a uniform distribution?

k	$\binom{54-5k}{48-5k}$
1	13 983 816
2	7 059 052
3	3 262 623
4	1 344 904
5	475 020
6	134 596
7	27 132
8	3 003
9	84

Table 3: The number, $\binom{54-5k}{48-5k}$, of *Lotto* tickets exhibiting property $k \in \{1, \ldots, 9\}$.

Suppose the six numbers played by a *Lotto* participant are ordered in natural order. We say that the numbers on a ticket exhibit *property* k if the absolute difference between any two consecutive numbers is at least some natural number $k \in \{1, \ldots, 9\}$. *Lotto* playing tickets exhibiting property k may be enumerated by counting the number of distinct ways in which 6 indistinguishable black balls and 43 indistinguishable white balls may be arranged linearly so that at least $k-1$ white balls appear between any two consecutive black balls. Such an arrangement may be achieved by initially placing

[1] The mechanism of choosing winning numbers in the United Kingdom National Lottery functions exactly the same as in the South African National Lottery. In both lotteries a participant also forms a ticket by selecting 6 numbers from a universal set of 49 numbers, and the jackpot ticket also comprises 6 numbers in both lotteries. Therefore these lotteries may be considered similar in nature.

$k-1$ white balls in each space between two consecutive black balls – there is only one way to do this – and then to augment the arrangement by distributing the remaining $49-6-5(k-1)=48-5k$ white balls anywhere amongst the spaces between the black balls of the partial arrangement currently comprising $6+5(k-1)=5k+1$ balls (including the two spaces before the first ball and after the last ball) – this may be done in $\binom{54-5k}{48-5k}$ distinct ways. This number of distinct tickets exhibiting property k is shown in Table 3 for various values of k.

Table 4 shows the probability, $P(N,m,\theta,k)$, that m participants win the jackpot if a certain proportion, θ, of the tickets purchased exhibit property $k=4$ and if $N=7.5$ million tickets are purchased in total. Notice how many orders of magnitude larger the probabilities in Table 4 are, compared to those in Table 1! However, even in the unlikely situation that *all* participant tickets exhibit property $k=4$ (*i.e.* if $\theta=100\%$ as denoted by the shaded entry in Table 4) the probability that 18 participants share the jackpot is still so small that one may expect to wait approximately 6207 years for such an unlikely event. Although this number is significantly down from a million times the age of the known universe under a relaxation of the innocent-looking assumption of participants choosing their *Lotto* tickets according to a uniform distribution, an expected waiting time of 6207 years certainly does not explain the particularly short waiting times of approximately 2.5 years between the extreme events of 31st October 2001 and 15th March 2003, and of approximately 6 years between the extreme events of 15th March 2003 and 7th February 2009. Since the number of tickets purchased per lottery draw typically varies between 7.5 million and 20 million tickets, the question arises how the expected waiting time between extreme events of multiple jackpot winners is affected if larger numbers of players participate in the lottery?

Table 5 shows the probability, $P(N,m,\theta,k)$, that m participants win the jackpot if a certain proportion, θ, of the tickets purchased exhibit property $k=4$ and if $N=20$ million tickets are purchased in total. Notice again how much larger the probabilities in Table 5 are, compared to those in Table 4! In particular, under the assumption that $\theta=20\%$ of the tickets purchased exhibit property $k=4$, the estimated probability of 18 participants winning the jackpot is 1.323×10^{-3} if $N=20$ million tickets are purchased (as denoted by the shaded entry in Table 5). This value implies that 18 participants should win the lottery jackpot prize approximately every 7.3 years. Similarly, under the assumption that $\theta=40\%$ of the tickets purchased exhibit property $k=4$, the estimated probability of 18 participants winning the jackpot rises to 2.637×10^{-3} if $N=20$ million tickets are purchased in total,

$N=7.5\times10^6$	$\theta=0\%$	$\theta=20\%$	$\theta=40\%$	$\theta=60\%$	$\theta=80\%$	$\theta=100\%$
$m=1$	3.137×10^{-1}	2.514×10^{-1}	1.891×10^{-1}	1.267×10^{-1}	6.439×10^{-2}	2.031×10^{-3}
$m=2$	8.412×10^{-2}	6.843×10^{-2}	5.274×10^{-2}	3.704×10^{-2}	2.135×10^{-2}	5.661×10^{-3}
$m=3$	1.504×10^{-2}	1.413×10^{-2}	1.324×10^{-2}	1.233×10^{-2}	1.143×10^{-2}	1.052×10^{-2}
$m=4$	2.017×10^{-3}	4.548×10^{-3}	7.086×10^{-3}	9.609×10^{-3}	1.215×10^{-2}	1.467×10^{-2}
$m=5$	2.163×10^{-4}	3.445×10^{-3}	6.675×10^{-3}	9.904×10^{-3}	1.314×10^{-2}	1.636×10^{-2}
$m=10$	4.291×10^{-10}	5.836×10^{-4}	1.167×10^{-3}	1.751×10^{-3}	2.334×10^{-3}	2.919×10^{-3}
$m=15$	≈0	8.754×10^{-6}	1.751×10^{-5}	2.623×10^{-5}	3.482×10^{-5}	4.361×10^{-5}
$m=18$	≈0	3.123×10^{-7}	6.155×10^{-7}	9.179×10^{-7}	1.230×10^{-7}	1.549×10^{-6}

Table 4: An estimate of the probability, $P(N,m,\theta,k)$, that m participants win the jackpot prize, assuming $N=7.5$ million tickets are purchased in total. These values were obtained from a Monte Carlo simulation ($1\,000$ iterations) and hold under the assumption that a certain proportion, θ, of the tickets purchased exhibit the property $k=4$ and that the numbers in the remaining proportion, $1-\theta$, of tickets are selected according to a uniform distribution, but that the numbers in the winning ticket are drawn according to a uniform distribution.

$N = 20 \times 10^6$	$\theta = 0\%$	$\theta = 20\%$	$\theta = 40\%$	$\theta = 60\%$	$\theta = 80\%$	$\theta = 100\%$
$m = 1$	3.422×10^{-1}	2.737×10^{-1}	2.057×10^{-1}	1.371×10^{-1}	6.856×10^{-2}	4.915×10^{-7}
$m = 2$	2.447×10^{-1}	1.958×10^{-1}	1.468×10^{-1}	9.785×10^{-2}	4.892×10^{-2}	3.674×10^{-6}
$m = 3$	1.167×10^{-1}	9.333×10^{-1}	6.993×10^{-2}	4.662×10^{-2}	2.333×10^{-2}	1.831×10^{-5}
$m = 4$	4.171×10^{-2}	3.338×10^{-2}	2.504×10^{-2}	1.670×10^{-2}	8.390×10^{-3}	6.830×10^{-5}
$m = 5$	1.193×10^{-2}	9.587×10^{-3}	7.261×10^{-3}	4.894×10^{-3}	2.547×10^{-3}	2.029×10^{-4}
$m = 10$	2.357×10^{-6}	9.777×10^{-4}	1.966×10^{-3}	2.946×10^{-3}	3.909×10^{-3}	4.879×10^{-3}
$m = 15$	≈ 0	1.969×10^{-3}	3.927×10^{-3}	5.902×10^{-3}	7.876×10^{-3}	9.846×10^{-3}
$m = 18$	≈ 0	1.323×10^{-3}	2.637×10^{-3}	3.961×10^{-3}	5.289×10^{-3}	6.615×10^{-3}

Table 5: An estimate of the probability, $P(N, m, \theta, k)$, that m participants win the jackpot prize, assuming $N = 20$ million tickets are purchased in total. These values were obtained from a Monte Carlo simulation (1 000 iterations) and hold under the assumption that a certain proportion, θ, of the tickets purchased exhibit the property $k = 4$ and that the numbers in the remaining proportion, $1 - \theta$, of tickets are selected according to a uniform distribution, but that the numbers in the winning ticket are drawn according to a uniform distribution.

implying that 18 participants should win the lottery jackpot prize approximately every 3.6 years. These expected waiting times are a much closer reflection of reality if one considers the extreme events of multiple jackpot winners in the South African National Lottery on the nights of 31st October 2001, 15th March 2003 and 7th February 2009, when there were 19, 33 and 18 jackpot winners, respectively.

The authors do not claim to have proof that large proportions of *Lotto* participants actually select tickets that exhibit property k – the above analysis merely shows:

1. how important it is to state and understand the assumptions underlying a statistical model of a stochastic real-world phenomenon,
2. how terribly constraining the innocent-looking assumption (i) above is (*i.e.* the assumption that players select the numbers which make up their *Lotto* tickets according to a uniform distribution), and
3. that a study of the actual numbers selected by participants is desirable (although this information is treated in confidence by the NLB) before one pronounces on the likelihood of extreme events involving large numbers of winners.

In conclusion, the authors disagree with Gilfillan's statement that "… the possibility of 18 identical selections of six numbers out of 49 is so low as to be 'almost' impossible …" – we have shown that it is possible to support analytically Naidoo's statement that there is "…nothing fishy about multiple *Lotto* winners" by altering Gilfillan's implicit model assumption (i) above to assumption (iii), without questioning whether the jackpot numbers are selected according to a uniform distribution during televised *Lotto* draws – *i.e.* by keeping assumption (ii) in tact.

In fact, we wager that there will be another extreme event of at least 18 jackpot winners in the South African National Lottery within the next six years, *i.e.* before the end of 2015!

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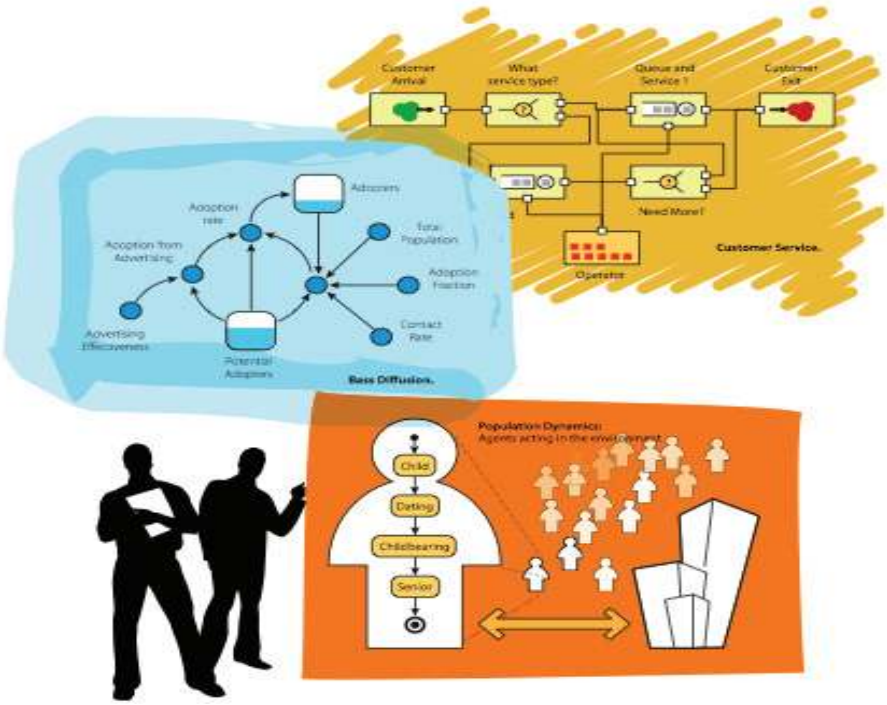

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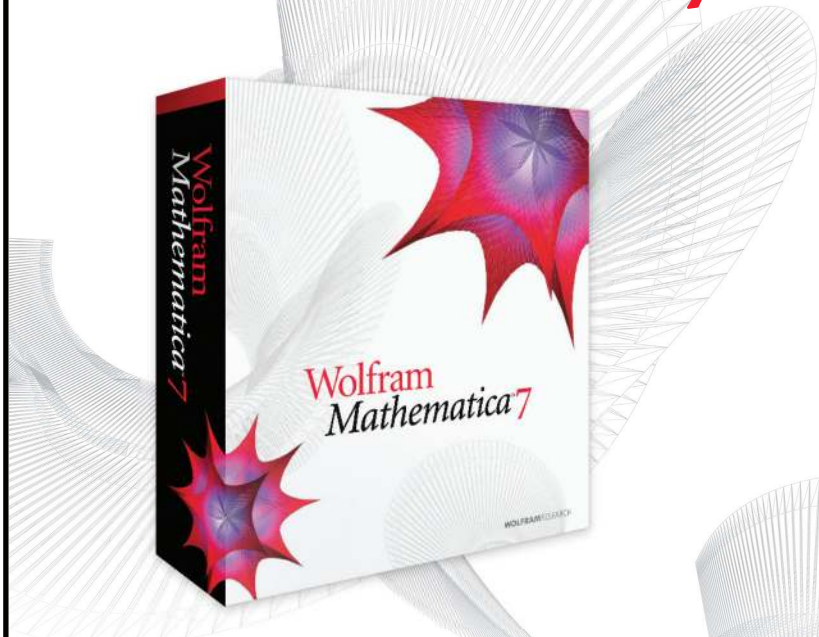

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