NEWSLETTER

June 2007

Operational Research Society of New Zealand, Inc.
PO Box 6544, Wellesley St. Auckland, New Zealand, www.orsnz.org.nz

Contents

The newsletter is published three to four times per year, regular dates are March, June, September, and December. Submissions deadline is the 15th of the month for the following month's issue. Send contributions by email to the Newsletter editor, Matthias Ehrgott, at newsletter@orsnz.org.nz.

Letter from the President

Recently (April 29 – May 1) I was invited to attend the 2007 INFORMS Conference on OR Practice in Vancouver. To summarize in just a few words – this was one of the most exciting and satisfying meetings I have attended in many years. I enjoyed this meeting so much that it started me thinking about why it was so special. Yes, Vancouver does happen to be a very attractive city to visit although I have to admit that my previous visits have had me en route to Whistler with more than just OR on my mind and on this visit I saw little of the city except from the bus on my way to and from the airport! But I can think of three obvious reasons why the INFORMS Practice meeting has made such an impression on me. Again in just three words, it was the *size*, the *quality* and the *focus*!

Anyone who has attended an INFORMS Annual meeting will easily appreciate the difference when it comes to size. In contrast to the 55 parallel streams and more than 3000 presentations at the Pittsburgh meeting in November, there were just eight parallel streams involving about 100 presentations in Vancouver. The much smaller size of the Practice meeting with 400 or so registrations compared to the 3789 registrations in Pittsburgh made for a much more intimate feeling – I was one of hundreds rather than one of thousands! My experience of the very large Annual meetings is also that there are usually many relatively low quality and uninteresting presentations and often a frustrating clash of topics; in contrast, all the presentations I attended at the Practice meeting (even in areas not so familiar to me) were of a uniformly high standard in both content and interest – perhaps this had something to do with the fact that most of the presentations were by invitation. But for me the most striking difference was the focus. As the name suggests, there was a clear emphasis on applications and practice. The streams were chosen to emphasize application areas such as Supply Chain Management, Business Optimization and Health Care Applications – take a look at http://meetings.informs.org/Practice07/Practice07Matrix-single3.pdf to get an indication of the applications focus for your selves. Unlike the Annual meeting, many of the conference registrants were from business and industry and a much smaller proportion were from academia. Again this is not hard to understand. It is unfortunately true that far too few academics in OR (especially in the US) have any interest in real practical applications but another telling point is the fact the registration fees for the Practice meeting are often beyond the means of poor academics even in the US!

But without doubt the highlight of this Practice Meeting was the stream on the first day highlighted as the 2007 Franz Edelman Award Competition. Because of my own presentation commitment, I didn't get to hear all of the five Edelman finalist presentations from Coca Cola

Enterprises, the US Coastguard, Hewlett-Packard, DaimlerChrysler and the Sloan-Kettering Cancer Centre but I am pleased to say I did get to hear the superb winning presentation. The winner of the 2007 Edelman Prize was announced at the Conference Banquet following a celebration of previous Edelman winners and a grand build up to the formal announcement. I have to say I think the judges got it right! The 2007 Edelman Prize was awarded to the Memorial Sloan-Kettering Cancer Centre for the work of Dr Marco Zaider, Attending Physicist in Medical Physics at Memorial Sloan-Kettering Cancer Center and Professor Eva K. Lee, Director of the Centre for Operations Research in Medicine and Healthcare in the School of Industrial and Systems Engineering at Georgia Tech. You can read about their work in more detail at http://www.informs.org/article.php?id=1281&p=1| but it involved the application of OR techniques in the treatment of prostate cancer. For me the most striking aspect of their work was the emphasis on the benefits being in terms of the improved quality of life rather than the usual emphasis on how many millions of dollars of savings the OR work had produced. That is not to say the work didn't generate millions of dollars of savings but as a male at the susceptible age in my life, the impact of Dr Zaider leaning forward and pointing at me (well, he was pointing at the judges and the audience but I felt it was at me!) and saying "the benefits are in terms of an improved quality of life for you" had a most reassuring effect! I just hope the technology crosses the Pacific soon and becomes available outside the US.

So if you ever have the chance to attend the INFORMS Practice meeting I really do recommend you take the chance even if it blows your travel and conference budget! INFORMS can be proud of what they have achieved in establishing the Practice Meeting as a highlight of their conference calendar. I look forward to the next opportunity I have to attend the meeting.

David Ryan

Wonderful World of Webs

Most of you won't have noticed, but we now do things slightly differently with our ORSNZ web site. Having set up a few web sites now, and managed the recent ORSNZ changes, I thought it might be useful to share my experiences.

Some time back, we bought the domain name *orsnz.org.nz* for the society from www.freeparking.co.nz at a cost of $39.95+GST p.a. I now prefer to use to www.discountdomains.co.nz who charge just $27.95+GST p.a. (as of 1 July). There may be even cheaper options out there.

Regardless of where you buy your domain name, you then have to set up name servers. Freeparking (and other name registrars) offer their own name servers. However, a better option is to use the free service offered by www.zoneedit.com. Using ZoneEdit gives you total control over your web presence. We use ZoneEdit to redirect all the ORSNZ email addresses, so, for example, vicepresident@orsnz... gets forwarded to my University mail address. We also use ZoneEdit to handle our web addresses. So, www.orsnz.org.nz is redirected to an address on one of the Engineering Science departmental computers. ZoneEdit also allows sub domains, so secure.orsnz.org.nz is redirected to the IP address of another machine in the department.

The ORSNZ is lucky in that the actual web servers are provided gratis by Engineering Science. I wanted to set up a personal web site, so was looking for an independent hosting provider. The cheapest option I found was US-based www.GoDaddy.com. For just US$3.99/month, they offer 5 GB of storage space, 250 GB of data transfers, 500 email accounts, forums, blogs, photos and even databases. This is a fraction of the cost of an equivalent service provided in NZ. GoDaddy also sell .com names at low prices, so I use ZoneEdit to redirect my .org.nz address to a .com address hosted by GoDaddy. The ORSNZ uses GoDaddy to buy the certificates it needs to provide security for our conference site secure.orsnz.org; they charge just US$20 a year, compared with NZ$112 from an NZ provider. It really pays to shop around.

I hope this information proves useful. All the best for your new web site!

Andrew Mason

PS: Thanks to Geoff Leyland for telling me about ZoneEdit.

PPS: I am not affiliated with any of the companies mentioned.

42ND ANNUAL CONFERENCE OF THE ORSNZ

29-30 November 2007 Auckland, New Zealand

Operational Research Society of New Zealand, Inc.
PO Box 6544, Wellesley St. Auckland, New Zealand, www.orsnz.org.nz

The Auckland Branch of the ORSNZ, the Operations Research group, and the University of Auckland are pleased to host the 42nd Annual Conference of the Operational Research Society of New Zealand, ORSNZ'07, on the 29 and 30 of November 2007.

Call for Papers

We welcome papers on all aspects of operations research, with particular emphasis on practical applications. Please email your abstract, in 200 words or less, in plain text, to the conference organisers at *conference@orsnz.org.nz*.

Submission deadline for abstracts: 5 October 2007.

Following acceptance of your abstract, we will invite you to submit a full-length paper for publication in the conference proceedings. A copy of the proceedings will be provided to every attendee at the conference. Full papers must be submitted by email in pdf format to the conference organisers.

Submission deadline for full papers: 31 October, 2007.

Registration forms, guidelines for the preparation of full papers, and further information about the conference, will be available on the conference website *conference.orsnz.org.nz*.

Student Grants-in-Aid for the ORSNZ Annual Conference

Full-time students, who are members of ORSNZ, and plan to present a paper at the ORSNZ conference, are eligible for travel assistance from ORSNZ to attend the conference. Applications should be made using the conference registration form (see *conference.orsnz.org.nz*), and should be signed by the student's supervisor or Head of Department to confirm that the applicant is enrolled in a full-time university course. The completed registration form, together with an abstract of the planned paper, should be sent to the conference address above by 5 October, 2007. Grants will be payable at the conference upon production of a GST receipt for the travel expenses.

Young Practitioners' Prize (YPP)

OR practitioners and students who will be under 30 years of age on 29 November 2007 are invited to compete for the ORSNZ Young Practitioners' Prize. Condition for entry is the presentation of a paper at the 42nd Annual Conference of the ORSNZ. When registering for the conference, competitors should request that their paper be scheduled in the YPP session and must provide proof of their eligibility. The total prize money awarded will be $1,000, split between the authors of the best papers at the judges' discretion.

Golbon Zakeri

People

One of the most respected members of the OR community, Ken Bowen, passed away on Friday 16th March 2007 aged 87. He died suddenly after going into his house from where he was working with his wife Barbara in his garden in his lovely home in Guilford. Being in the field of Operational Research for so many years he had a good overview of what was going on. Ken became a well-known and much respected scientist whose knowledge greatly exceeded the boundaries of his own field. Ken Bowen started as a mathematician and, over the years, gravitated towards broader areas to do with problem-formulation, conflict resolution, strategy, and decision structures. He dedicated the last 25 years of his life to science, emphasizing that complex societal problems can be better handled in a scientific and practical way, instead of starting a war over it. In this regard one of his last publications is very interesting to read see:
http://www.geocities.com/doriendetombe/detombeMMvolmue8terrorism.html

From the EURO Newsletter

Chapter News

Auckland News

The Auckland Branch of ORSNZ continues to be active on many fronts. We have had short visits early in the year from Danny Ralph from the University of Cambridge and Rüdiger Schultz from Duisburg-Essen. Currently Professor Mike Trick of the Tepper School of Business at Carnegie-Mellon University is visiting the Department of Engineering Science on a Hood Fellowship until the end of this year. He will be a plenary speaker at this year's ORSNZ Conference in Auckland along with Professor Gerard Cachon from the Wharton School, who is spending a sabbatical year in Auckland from September.

On May 17th the Auckland Branch hosted a social function after the University of Auckland Hood Lecture by Mike Trick entitled: "Operations Research: The Science of Better". This public lecture, reported on elsewhere in this Newsletter, drew an audience of approximately 100 people from the Auckland region. It was very gratifying to see such a large turnout. Gazing around the audience, this correspondent noted Phil Bishop (from the Electricity Commission) who had flown up from Wellington, Jim Corner who had come up from Hamilton for this talk, Merv Rosser, who we all know as a life member of ORSNZ, Jeff Meyer and Cory Williams from Optima Corporation, the Engineering Science graduates who now work in Derceto, and Geoff Leyland from Incremental. There were also many people there I did not know, who evidently work in Auckland in an OR-related field.

Mike's public lecture was the most outstanding call-to-arms that I have heard from an OR person – even better than Gene Woolsey at the ORSNZ Conference in 1978. Drawing from the histories of well-known companies, including FedEx, Google, and the US Postal Service, Mike presented the audience with a convincing argument that OR is an essential part of making businesses successful. His thesis: without OR, these companies would not exist in their present (or any) form. The lecture was stimulating, informative, convincing, and amusing.

The evening was rounded off well with a social function sponsored by ORSNZ. A number of enquiries were made at this function about the Society and its purpose. Most gratifying was seeing the number of people at the talk who now work in an OR related field – enough to want to come and hear such a talk. The challenge for the Society is to encourage the same people to come and present what they are doing at the ORSNZ Conference.

The remaining news from the Auckland Branch is more along the lines of gossip. Andrew Mason and Catherine Swan now have a lovely baby daughter Margaret, who often visits Andrew's office. (I think that she is doing some programming for him). Andrew is on sabbatical leave this semester. Matthias Ehrgott goes on sabbatical in the next semester. Tony Downward, Andrea Raith, Oliver Weide, Richard Lusby, Golbon Zakeri and Andy Philpott are travelling to Prague in July for the EURO 2007 meeting. Tony and Golbon will be visiting universities in the US on their return trip. Andrea will continue to Nantes, France, and Richard will once again visit Copenhagen to improve his Danish language skills. Dave Ryan is off to Atlanta in July to present at George Nemhauser's 70th birthday symposium. Cameron Walker and Michael O'Sullivan are planning a visit to California later this year to work with colleagues there on network design problems.

Andy Philpott

Canterbury News

As usual the Canterbury branch is full of quiet activity.

Our two most recent PhD graduates are Dr Paul Stewart and Dr James Tipping. Both Paul and Jimbo wrote theses in the broad area of the New Zealand electricity market. Both were in the same year of Honours and shared many undergraduate classes, often vying for the top mark in a class. Both of these new doctors also managed to finish their theses and have oral examinations just in time to graduate in person at this years April graduation ceremony. And now, both Dr Stewart and Dr Tipping are working in operations research positions in London. Paul arriving in London just as his brother, Dr Mark Stewart a previous PhD graduate of ours, leaves on a slow journey back to New Zealand.

This semester we also hosted another previous student, Steve Batstone, all the way from Auckland. Steve has been returning to UC each year to teach our honours students about electricity markets with Grant Read.

On the subject of teaching, one reason for our 'quiet activity' is a re-organisation of our undergraduate teaching. We are combining courses to better suit the current needs of our students and teaching staff. This process has naturally involved a lot of work behind the scenes. Our new offerings strangely resemble the offerings the department had just before I joined UC in 1998. It seems that the iterative nature of the OR-process, that I have been continually teaching my under graduate students, is coming back to haunt me. We have also re-organised our honours program to fit the new requirements of our, determinedly outstanding, Science faculty.

While many of our staff are busy with these changes, others are busy with other things. Terri Green is in the middle of her sabbatical and Venkat is still acting MBA director. Don McNickle and Pavel Catska are just at, or newly returned from international conferences, both of which have taken them to Prague.

Shane Dye

Waikato News

Les Foulds retires at the end of June 2007 from the Department of Management Systems of the Waikato Management School.

Recently, he was invited to recount some his memories of the nearly 22 years that he has spent at the University of Waikato. Here are some highlights of his reminiscences. When he arrived in 1985, Waikato had about 3,000 students, and a small, but rapidly increasing number of academic staff in the Management School – with only one other of them having a PhD. His mandates, as the new Professor of Management Studies, were to help with regard to: "Resurrecting operations management", "Getting research going in the School", and "Splitting the School into seven departments". There were no PCs, no Internet, and an unbelievably conservative, federally controlled funding system that defied innovation.

Some of the many lighter moments include:

- The frowning response from one of the support staff who, upon being asked to type-set an OR article for journal submission, responded with, "We don't accommodate hobbies!"
- The student evaluation, "Les' course is a good cure for insomnia".
- The consulting client who asked, "When the University computer has a spare moment please ask it…"; and
- Playing in class a case study tape that had previously been lent to a student, only to find that the content had been replaced by hardcore pornography. At least it had the desired affect of refocusing student attention.

Les has had significant association with ORSNZ for over 30 years. He served as its President for over three years and was awarded the ORSNZ Hans Daellenbach Prize in 2003. Les would like to thank his ORSNZ colleagues for their support and friendship. Les is to become an Adjunct Professor in an OR research institute at a federal university near Brasilia. Consequently, Les and his wife Eva will soon live permanently in central Brazil.

Chuda Basnet

Wellington News

The School of Mathematics, Statistics and Computer Science at Victoria University of Wellington is home to lots of mathematicians, statisticians and computer scientists, and a few members of the rare species of operations researchers. Between us, we currently teach four undergradu-

ate courses and three postgraduate courses in statistics and operations research.

In the past year, we have all been overseas. In August, A/Prof Stefanka Chukova visited Tokyo (Japan) and Busan (South Korea) where she organized a special session on Advanced Warranty Modeling at the 2006 Asian International Workshop on Advanced Reliability Modeling (AIWARM 2006). Stefanka also visited Bulgaria in June, where she attended the 12th International Summer Conference on Probability and Statistics in Sozopol. Over the summer, Dr Mark Johnston attended PlanSIG at Nottingham (England), visited research collaborators in Bristol and Colchester, and got married to the lovely Emily in a little English country village. Prof Tony Vignaux and Dr Tapas Sarkar are both enjoying their retirements, despite being roped into helping out from time to time. Tony took his wife on a cruise around the Baltic, and Tapas visited friends and relatives in India. Recent visitors to the group include Prof Harry Perros from North Carolina State University (reliability of optical computer networks) and Prof Dimitar Christozov from American University in Bulgaria (warranty issues linked to malfunctioning and misinforming).

Two of our recent graduate students, Sarah Marshall and Tineke Poot, have been accepted into the PhD programme at Edinburgh University, and will begin their studies in September. Our recent Canadian undergraduate exchange student, Deborah Loach (now at the University of Windsor), has won the poster prize at the Canadian Operational Research Society conference. With Prof Tony Vignaux, she developed a simulation model of non-emergency calls for the New Zealand Police.

The highlight of our week is undoubtedly "OPRE Idol", an informal seminar involving academic staff, postgraduate students and keen undergraduate students. OPRE Idol began life with everyone bringing along their favourite topic from Operations Research. Unfortunately we haven't been allowed to vote anyone off as yet. We have covered topics such as Markov Chain Monte Carlo simulation, stochastic programming, dynamic programming, and combinatorial optimization, as well as discussing our current research and eating gingernut biscuits.

Mark Johnston

Sudoku and OR

Federico Della Croce
Dipartimento di Automatica e Informatica
Politecnico di Torino
E-mail address: federico.dellacroce@polito.it

Keywords: Combinatorial Optimization, Integer Programming

1 Introduction

Following the description of Wikipedia the free encyclopaedia [6], Sudoku can be described as a logic-based placement puzzle. See [3] for an efficient Sudoku solver on the web. The aim of the classic version of the puzzle is to enter a numerical digit from 1 through 9 in each cell of a 9×9 grid made up of 3×3 subgrids, starting with various digits given in some cells (the givens); each row, column, and region must contain only one instance of each numeral. Further only proper puzzles are considered, that is puzzles having a unique solution. Below are reported a classic Sudoku proper puzzle and the corresponding solution.

				6		1	7	3
	2		5		3			
7						2		
4			6					9
2								8
5					4			2
		6						5
			8		6		4	
8	4	7		9				

9	8	5	4	6	2	1	7	3
6	2	1	5	7	3	8	9	4
7	3	4	1	8	9	2	5	6
4	7	3	6	2	8	5	1	9
2	6	9	7	5	1	4	3	8
5	1	8	9	3	4	7	6	2
1	9	6	2	4	7	3	8	5
3	5	2	8	1	6	9	4	7
8	4	7	3	9	5	6	2	1

The Sudoku puzzle was invented in Indianapolis in 1979 but reached widespread international popularity just in 2005 after being launched at the end of 2004 by one of the leading British newspapers, "The Times". A nice scientific survey of the Sudoku phenomenon was presented in [1]. Several variants have been proposed of the

Sudoku puzzle. We cite among others SudokuX, where as additional constraint it is required that also the main diagonals must contain only one instance of each numeral. Alphabetical variations have also emerged (the so-called Wordoku): there is no functional difference in the puzzle unless the letters spell something. Some variants include one or two words reading somewhere in the grid once solved, where this/these word/s are described as in crosswords: determining the word in advance can be viewed as a solving aid. Below are reported a Wordoku puzzle using letters (A - B - C - D - I - N - R - V - Y) and the corresponding solution.

The current president of the New Zealand OR Society

			I				Y	N
	A	○		C				
	R		○					V
	D			○	C		A	
	C	V		N	○	R	B	
○	I		Y			○	V	
V	○						N	
		○		D			I	
D	B		○		R			

B	V	C	I	R	D	A	Y	N
N	A	**D**	V	C	Y	I	R	B
I	R	Y	**A**	B	N	C	D	V
Y	D	B	R	**V**	C	N	A	I
A	C	V	D	N	**I**	R	B	Y
R	I	N	Y	A	B	**D**	V	C
V	**Y**	R	C	I	A	B	N	D
C	N	**A**	B	D	V	Y	I	R
D	B	I	**N**	Y	R	V	C	A

2 Solving proper Sudoku puzzles by means of ILP modelling

Every proper Sudoku puzzle can be tackled by means of various AI & OR techniques. For instance, on one hand the puzzle can be solved by means of constraint programming techniques (see [5]) such as the all-different operator, on the other hand it can be easily formulated as an ILP model. Here we focus on this latter approach. Given an initial grid where some elements (i,j) already been filled by digits, let $RQ\text{-}h$ (h = 1, ..., 9) be the h^{th} block of the grid. An ILP formulation (P1) of the Sudoku puzzle can be expressed as follows:

Variables:

$x_{i,j,k} = 1$ if element (i,j) has value k ($1 \le k \le 9$, k integer) in the puzzle solution, else $x_{i,j,k} = 0$.

Objective function:

There is no objective function as the purpose is just to search for a feasible solution.

Constraints:

(1) $\sum_{k=1}^{9} x_{i,j,k} = 1$ for all i, j (each element of the grid contains one of the digits 1 – 9)

(2) $\sum_{j=1}^{9} x_{i,j,k} = 1$ for all i, k (each row of the grid contains the digits 1 − 9 exactly once)

(3) $\sum_{j=1}^{9} x_{i,j,k} = 1$ for all j, k (each column of the grid contains the digits 1 − 9 exactly once)

(4) $\sum_{i,j:(ij)\in RQ-h} x_{i,j,k} = 1$ for all h = 1, …, 9 for all k = 1, …, 9 (each block of the grid contains the digits 1 – 9 exactly once)

(5) $x_{i,j,k} = 1$ for all elements (i,j) of the entry grid with value k.

3 Building proper Sudoku puzzles by means of ILP modelling

To build a proper Sudoku puzzle, we need to derive an initial grid such that there exists a feasible Sudoku solution compatible to that grid and this solution is unique. Below (see [2]) is indicated how to check whether a solution (given an initial grid) is or not unique. Let denote by $SOL(i,j)$ the value of element (i,j) of the grid in the feasible solution. Consider solving the following ILP model (P2):

Objective function:

$$\min Z = \sum_{i,j,k:SOL(i,j)=k} x_{i,j,k}$$

(We minimize the sum of all variables $x_{i,j,k}$ corresponding to elements (i,j) having value k in the feasible solution).

Constraints:

The same constraints (1) – (5) considered in model P1.

The solution of model (P2) clearly provides a feasible solution also to model (P1) and therefore to the Sudoku puzzle. Further, the objective function of model (P2) minimizes the sum of the elements in the grid having the same value ob-

tained in the solution of model (P1).Hence, as each grid is composed by 81 elements, if the objective function value of model (P2) is equal to 81 ($Z = 81$), then the considered Sudoku puzzle has unique solution, else the solution to the Sudoku puzzle is not unique.

A straightforward approach for building a proper Sudoku puzzle is provided by the following procedure (notice that the sequence indicated below for emptying the elements is not compulsory, but it is sufficient to handle all elements under any sequence).

```
Procedure "Build_initial_grid":
INPUT: final solution.
OUTPUT: initial grid.
{
for i=1 to 9
 for j=1 to 9
  fill element (i,j) with Sol(i,j);

for i=1 to 9
 for j=1 to 9
  empty element (i,j);
   Solve model P2;
   if the objective function value
    of model P2 is < 81
    (solution not unique),
   then
    fill element (i,j) with SOL(i,j);
 end for
end for
}
```

This approach guarantees that the corresponding Sudoku puzzle is also irreducible, namely no element (i,j) can be emptied, or else the solution becomes not unique.

4 A challenging problem for the OR community

From an OR point of view, solving/building a proper Sudoku puzzle is actually quite a trivial task. However a strongly challenging combinatorial problem related to the Sudoku puzzle is concerned with the minimum number of givens for proper puzzles (notice that the inverse problem, that is the maximum number of givens that can be provided while still not rendering the solution unique has a trivial solution, namely four short of a full grid). The best available solution value for this problem is 17 (see [4] for a collection of distinct Sudoku proper initial grids with 17 givens) and it is conjectured that no16-givens initial grids exist, evidence for which stems from extensive randomised searching. On the other hand, a trivial lower bound of 8 can be determined for this problem: indeed if two numerals k, l are absent from the initial grid, then there exist at least two different solutions (it is sufficient to assign value k to all elements having value l and vice versa). However, to the author's knowledge, at the current state of the art no better lower bound is available: this induces indeed quite an impressive gap and room for extensive research!

References

[1] J. P. Delahaye, The Science behind Sudoku, (June 2006), Scientific American, 71-77.

[2] F. Della Croce, G. Ferro, Sudoku per l'estate, Mondadori, 2006 (in Italian).

[3] C. Frayn, Generate and solve Sudoku puzzles, http://www.frayn.net/sudoku/.

[4] G. Royle, Minimum Sudoku, http://www.csse.uwa.edu.au/gor-don/sudokumin.php

[5] H. Simonis, Sudoku as a constraint problem, in CP Workshop on Modeling and Reformulating Constraint Satisfaction Problems, 13-27, Sitges (Barcelona), October 2005.

[6] Sudoku, from Wikipedia: http://en.wikipdia.org/Sudoku.

Puzzle Corner

PUZZLE 9

A family gathering comprises: a father, a mother, a son, a daughter, a brother, a sister, a cousin, a nephew, a niece, an uncle, and an aunt. But only two men and two women are present. All four people have a common ancestor and there have not been any consanguine marriages. How is this possible?

SOLUTION TO PUZZLE 8

A total of 12 moves or jumps forward.

Tactical High-Level Simulation of Robustness in Train Schedules

Line Frølund Madsen
Decision Science, PA Consulting Group
Michael Folkmann
DSB S-tog A/S
Knud Erik Wichmann
Decision Science, PA Consulting Group

PA Consulting Group
Tuborg Boulevard 5
DK-2900 Hellerup
Line.Frolund.Madsen@paconsulting.com

Abstract

This paper demonstrates the relevance of high-level tactical simulation models to support the development and validation of new concepts; in theory and in a case study.
A *high-level* model has a high level of abstraction in modelling and data details. A *tactical* model is used in the long term development and planning phase; not for strategic decisions and not in the daily planning or detailed validations.
Simulation tools traditionally used in the railway sector are usually data-intensive. These models are very important in the final validation of train schedules but not flexible enough for rapid comparison of multiple proposed solutions. Therefore, only a few scenarios and concepts are usually defined, validated and compared with such detailed models, which limits development.
PA Consulting Group developed a tactical high-level simulation model of the Copenhagen urban train network in a project with DSB S-tog. The model was used to compare two train schedule concepts with respect to robustness. The model was used to test a new concept rather than the specific details of the train schedule, and therefore not limited by all the detailed constraints in the infrastructure. New Key Performance Indicators (KPIs), designed with the purpose of comparing and especially capturing robustness, were introduced – e.g., punctuality measures, time between departures, accumulated secondary delays and slack utilization.
The project demonstrated a clear difference in robustness of the two concepts – and stated a number of reasons for this difference.

Use of high-level tactical simulation models

Today, in the railway sector, there is a continuous need for developing new or updating existing train schedules to satisfy customer demands, to remain competitive and to adapt to changes in the infrastructure. Besides the complex process of designing train schedules, one of the main complications is to ensure robust train schedules. In this paper the definition of robustness covers elements such as stability, need for recovery, and ability to absorb delays. Several KPIs including punctuality, accumulated secondary delays and slack utilization define robustness. These will be described and used later in the paper.

When trains share tracks, a train network becomes a dynamic and volatile system with a high level of interdependencies between various trains. As a result, a *primary delay* caused on one train is likely to cause *secondary* or *'knock-on' delays* of other trains. Weather, passengers, crew, and problems with the infrastructure etc. cause a primary delay, while a secondary delay is caused by a primary or secondary delay of another train. It is very difficult to predict the magnitude and behaviour of the secondary delays in the network, and since they propagate, these delays have significant impact on the punctuality and robustness of the train schedule. Consequently, the real-life behaviour and robustness of the system is difficult to analyze and predict using conventional analytical methods.

One way of validating train schedule concepts with respect to robustness is to use a *high-level tactical simulation model early in the development of the train schedule*.

A *high-level* model has a high level of abstraction in modelling and data details. A *tactical* model is used in the long-term development and planning phase; not for strategic decisions and not in the daily planning or detailed validations.

The argument of using high-level tactical simulation models leads to the questions "Why use simulation?", "Why use high-level tactical models?", and "Why use simulation early in the development phase?" These answers are examined in the following sections and further supported in the case study.

Why use simulation?

- For analyzing the secondary delays and the interdependencies in a train network.

- Simulation will allow the dynamics and interdependencies in a train network to be analysed. In discrete-event simulation, the infrastructure can be modelled to the necessary level of detail but most importantly, the events in the network are modelled to reflect the real world in the best possible way; a train is held back when a primary delay is introduced and secondary delays will appear as all other affected trains are held back as a consequence of the primary delay. When using simulation, the magnitude and behaviour of the critical secondary delays can be analysed.
- Simulation is a safe test environment ideal for validating new ideas prior to implementation. Some of the iterations of testing and adjusting to optimize a process or a system can be done in the simulation phase before the implementation. Furthermore, the stability of a system or train schedule can be verified by running several replications of given scenarios.
- Simulation can be used for identifying specific problem areas such as bottlenecks within a system and provide understanding of the interaction of various components.

Why use high-level tactical models?

➢ For supporting continuous development.

For a company to maintain development and growth it is important to encourage new ideas and 'out of the box' thinking and thus also important to have appropriate tools to validate these new ideas. Tactical models with a high level of abstraction in model and data detail are easily adapted to test new scenarios and can be used to indicate whether new ideas are worth developing further.

High-level simulation models based on the basic element of the system can be used to rapidly validate and test new ideas and concepts without operational concerns and with the possibility of, e.g., developing new train schedule concepts that do not necessarily fit the current infrastructure entirely [4]

Why use simulation early in the development phase?

- For reducing risk and supporting decision-making.

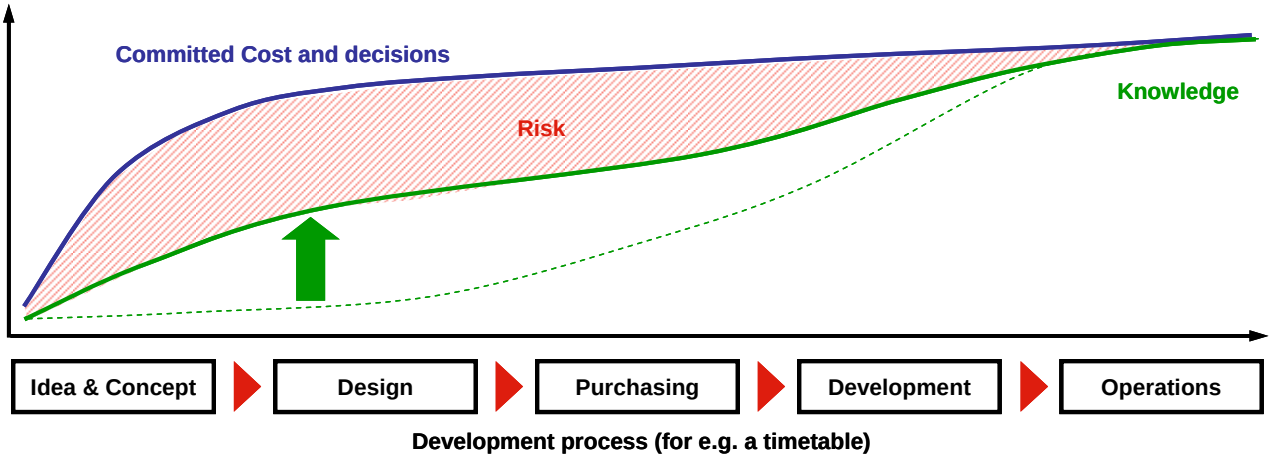


Figure 1: Identified risk

Figure 1 shows a conceptual development process [5]. As shown in the Figure, the knowledge of the system is sparse early in the development phase while decisions with great impact and often high costs must be made. The gap between the committed cost and the knowledge is identified as the risk related to the decisions made.

Knowledge and consideration of every detail is not needed to build a model that can help indicate the right directions. By using high-level models early in the development phase, knowledge about the system is improved and hence decision-making can be supported and the risk can be reduced.

The arguments in favour of using high-level tactical simulation models for validating new ideas and concepts are the same for many branches of industries, whether it concerns constructing new factories, designing production lines, optimizing working procedures or designing new train

schedules. In the next section, a case study demonstrating the use of a high-level simulation model in the railway sector is examined.

Case study – validation of a train schedule concept

DSB S-tog, the Danish railway company responsible for running the Copenhagen urban train network, looked into the possibility of a new concept for a train schedule expected to be less sensitive to delays because of a more homogeneous stopping pattern. The challenge was to validate whether this *new concept* would result in higher robustness and improved customer satisfaction before adjusting it to the actual infrastructure and implementing it. PA Consulting Group developed a high-level discrete-event simulation model of the S-train network. The objective of the project was *not* to validate the train schedule according to the given infrastructure, as done with the detailed simulation models often used in the railway sector. The objective was to validate the *concept* of the train schedule. The validation was performed by comparing the *new concept* with a *known concept,* with respect to specific KPI covering robustness.

The overall modelling approach is based on a generic segment of the train network as seen in Figure 2, where a platform on a station and the route to the platform on the next station are considered generic. The main activities in this generic segment are:

a) Dwelling: station-dependent dwell time (minimum dwell time if the train is late and scheduled dwell time if the train is on time)

b) Delaying: primary delay for the entire segment is added (samples based on historical data)

c) Waiting: the train waits for headways (the minimum safety distance between two consecutive trains) to be satisfied in order to fulfil safety requirements

d) Running: the train runs to the next station (using a minimum running time if delayed and scheduled running time if the train is on time)

e) Waiting: the train waits for permission to enter the next station (the platform must be vacant and safety restrictions fulfilled).

This is a conceptual picture of both the real world and the model used to validate the new concept, but indicates how the generic model is built. Further details, especially for the terminals, are modelled but are beyond the scope of in this paper. The model is validated to the purpose and tested thoroughly with respect to the expected events. For further details on the model and verifications see [2] and [3].

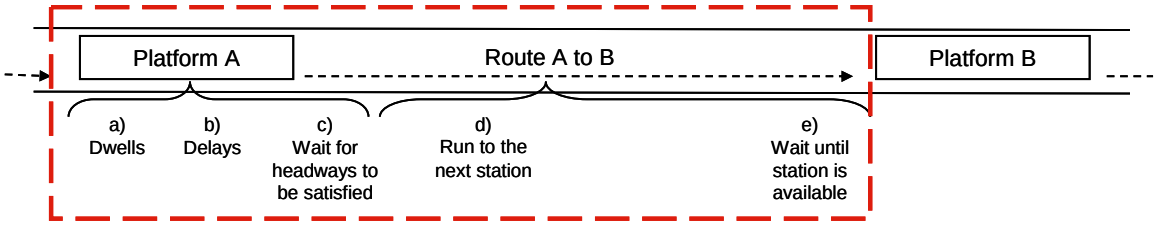


Figure 2: A generic segment of the train network

Key performance indicators describing the robustness of the train schedules

To validate the new concept with respect to robustness, a series of KPIs were used, including:

- Punctuality
  - percentage of trains arriving no later than 2.5 minutes after the scheduled arrival time
- Quantity of secondary delays
  - accumulated sum of secondary delays for all trains and departures
- Slack utilization
  - use of the slack time, where slack is the extra time added in the timetable. The slack time is added to create a buffer in the schedule
- Quantity of 'close departures'
  - number of departures with less than three minutes in between
- Consequence of close departures

– correlation between 'close departures' and secondary delays
- Actual time between arrivals
- Actual travel time between stations.

The two concepts

The following tables describe the main characteristics, strengths and disadvantages of the two concepts.

Known concept	New concept
Characteristics:	
Fast trains and stop trains: – Fast trains skip smaller stations – Stop trains stop at every station on the line	Exclusively stop trains – Stop trains stop at every station on the line
8 different cyclic train schedules	3 different cyclic train schedules
10 lines through the central area/bottleneck of the network	10 lines through the central area/bottleneck of the network
Strengths:	
Complex line patterns to satisfy passenger demand	Homogeneous line patterns to decrease interdependencies
Fast trains to satisfy passengers travelling to the terminals	Only stop trains for simplicity
Challenges:	
Low punctuality	New and untested principles
Cancellations	Uncertainties concerning benefits – E.g. longer travel times vs. higher punctuality

One of the main differences between the two concepts is the difference in the level of homogeneity, due to the combination of fast and stop trains in the known concept and the exclusive use of stop trains in the new concept.

Figure 3 demonstrates this difference. Figure 3 shows the time of departure for trains running from one end of a line to the other. The difference in time of departure between two consecutive trains, as also shown in the Figure, indicates the degree of interdependencies between these two trains; because the less time between two departing trains on the same station, the more likely it is that the first train will affect the next if disturbances occur. The Figure of the Known concept shows:

– The time between departures increases between the *first fast train* and the *first stop train* as the train is moving from one terminal to the other. Hence the interdependencies between these trains decrease.

– This also means that the time between departures of the *first stop train* and the *second fast train* in the periodic cycle decreases, hence the interdependencies increase.

This is not the case in the new concept where the time between departures is constant, as seen in the Figure for the new concept.

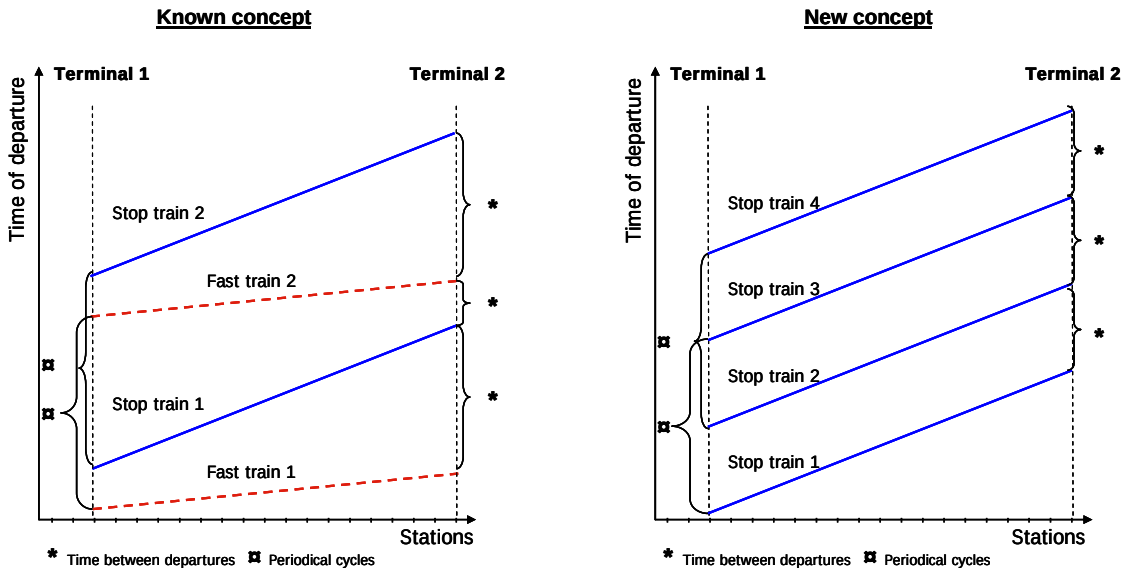


Figure 3: Principles of time between departures from one terminal to the other

The new concept would lead to a much more robust train schedule

Using the high-level simulation model, the two concepts were compared and the new concept was validated. The analysis indicated a significant improvement in robustness, as shown in the following results.

- Higher punctuality.

Figure 4 shows the punctuality of the two train schedule concepts for added delays between maximum zero and maximum two minutes. As expected, the punctuality for both train schedules decreases as the primary delay is increased. But the punctuality of the Known concept decreases at a greater rate and the slope of the curve changes abruptly at a certain point, indicating that there is a limit to the acceptable level of primary delay. Hence, not only does the new concept result in a much higher punctuality in this simulation, it is also more stable and less sensitive to the exact amount of added delay, as seen on the shape of the curves.

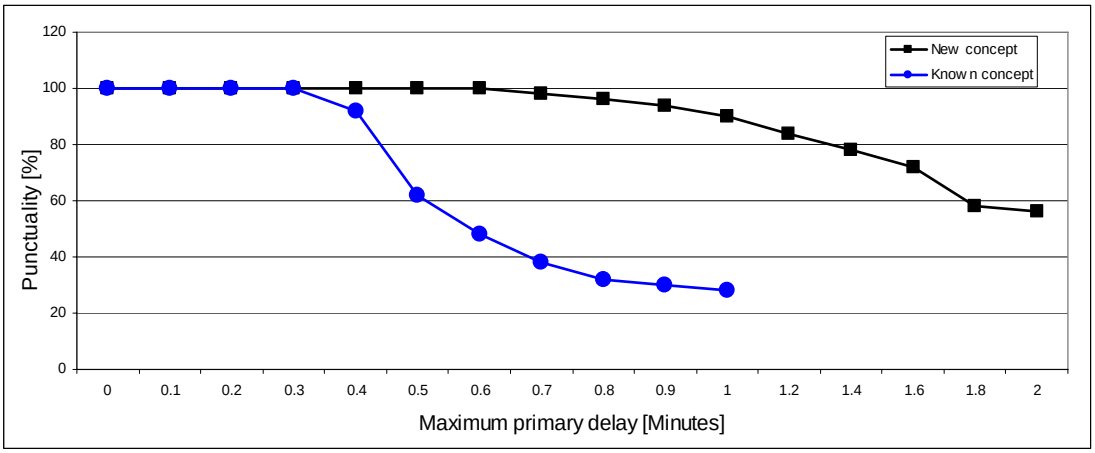


Figure 4: Punctuality as a function of primary delays

- Less accumulated secondary delay.

The accumulated secondary delay in the new concept was considerably lower than the Known concept. This indicates that there are fewer interdependencies between departures in the new concept. When comparing the two concepts, the amount of 'close departures' (departures with less than three minutes in between) is counted to be approximately 30% less in the New concept; a result of not mixing fast and stop trains. The simulation shows that secondary delays primarily occur on the 'close departures'. This supports the intuition that the close departures have a very high impact on the secondary delays that are a critical element in our definition of robustness.

- Maintaining train order.

If possible, the trains should enter and leave the central area (the main bottleneck in the network) of the network according to the scheduled order. This means that dispatchers manually restore the order when the schedule is not followed. In comparison with the Known concept, the new concept had very few permutations of the scheduled order, which in practice would mean less need for recovery of the new concept and therefore less work for the dispatchers.

- Lower slack utilization.

The utilization of the added slack (buffer) was significantly lower in the new concept compared to the Known concept. This indicates that the new concept is more stable and that primary delays are absorbed without spreading as secondary delays. Another indication is that less slack or buffer is necessary in the new concept, which can help decrease the travel times.

- Not longer effective travel times.

The scheduled travel times between the central area and the terminals are shorter in the Known concept because of the fast trains. However, because of higher punctuality in the new concept, the actual travel times, when primary delays are added, are not prolonged to the same extent as in the Known concept. The New concept is not affected by secondary delays to the same extent as the Known concept; hence the effective travel times are closer to the scheduled. Figure 5 shows the travel times. When a certain amount of pri-

mary delays are added, the average travel times in the Known concept supersedes the travel times of the new concept. This indicates that the robustness of the schedule is just as important as the design.

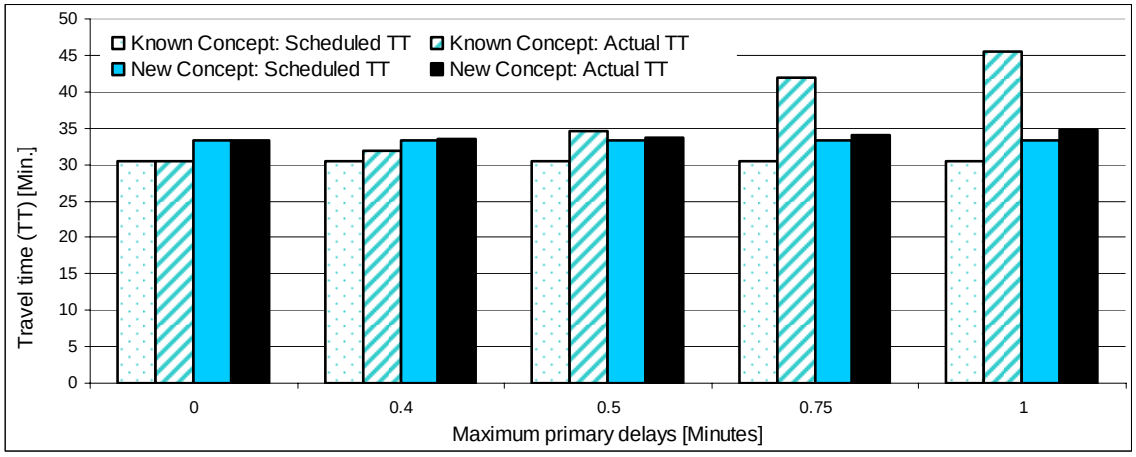


Figure 5: Travel times (TT) between the central area and the terminals (average of all travels)

Conclusion

This paper demonstrates the relevance of tactical high-level simulation models to support development and validate new ideas early in the development phase; in theory and in a case study. A *high-level* model has a high level of abstraction in modelling and data details. A *tactical* model is used in the long-term development and planning phase; not for strategic decisions and not in the daily planning or detailed validations.

PA Consulting Group developed a tactical high-level simulation model of the Copenhagen urban train network in a project with DSB S-tog. The model was used to compare two train schedule concepts with respect to robustness. The project demonstrated a clear difference in robustness of the two concepts; shown by higher punctuality, less secondary delays, lower slack utilization and shorter actual travel times.

Even though the analysis indicates that the new concept results in a more robust train schedule, this does not mean that the train schedule based on the new concept can be implemented immediately. By using the tactical high-level simulation model, the concept is validated, the knowledge about the new concept is improved and the decisions for pursuing the work with this new concept are supported. The next steps are to validate the train schedule according to the actual infrastructure and make adjustments to both the timetable and the infrastructure to realize the benefits of this new concept. This means that the train schedule is now ready for further development, using more detailed models after this high-level tactical evaluation.

References

[1] K. E. Wichmann and D. D. Mayo (2003) *Tutorial On Business And Market Modelling To Aid Strategic Decision Making: System Dynamics In Perspective And Selecting Appropriate Analysis Approaches*; Winter Simulation Conference 2003, New Orleans; Decisions Science, PA Consulting Group, 2003

[2] M. Hofman and L. Madsen (2005); *Robustness in train scheduling, Master's Thesis*; Technical University of Denmark, DTU, 2005

[3] M. Hofman, L. Madsen, J. Groth, J. Clausen and J. Larsen (2006); *Robustness and Recovery in Train Scheduling - a simulation study from DSB S-tog a/s*; Technical University of Denmark, DTU, 2006

[4]M. Vroman, R. Dekker and L. Kroon (2003); *Reliability and heterogeneity of railway services*; ERIM Research Report ERS-2003-090-LIS; Erasmus University Rotterdam, 2003

[5] N. E. Larsen and M. Nordstrøm (2006); *Reducing the Cost and Increasing the Business Value of New Postal Sorting Facilities*; Decisions Science, PA Consulting Group, 2006

19th International Conference on Multiple Criteria Decision Making

MCDM for Sustainable Energy and Transportation Systems

The University of Auckland, Auckland, New Zealand

7-12 January 2008

Website mcdm2008.orsnz.org.nz

Email mcdm2008@esc.auckland.ac.nz

Call for Papers and Sessions

The 21st century heralds an age of exponentially increasing demand for energy and transportation services in a globalised economy. Climate change and other environmental impacts of human economic activity necessitate the consideration of conflicting goals in decision making processes to develop sustainable systems. The science of multiple criteria decision making has a lot to offer in addressing this need. The International Society on Multiple Criteria Decision Making (MCDM) is organising its 19th International Conference under the theme MCDM for Sustainable Energy and Transportation Systems.

Abstracts are now called for and should be submitted by email to mcdm2008@esc.auckland.ac.nz. All areas of MCDM are welcome and papers related to the theme of the conference are especially encouraged.

- Multiple Criteria Decision Aiding
- Multiple Criteria Classification, Ranking, and Sorting
- Multiple Objective Continuous and Combinatorial Optimisation
- Multiple Objective Metaheuristics
- Multiple Criteria Decision Making and Preference Modelling
- Fuzzy Multiple Criteria Decision Making

(Extended) abstracts should be up to two A4 pages in 12pt font or similar. Abstracts must contain the name and affiliation of all authors, plus the email address of the corresponding author for notification of acceptance. Abstracts can be submitted in plain text, Latex, or Word formats, but postscript and pdf files are not acceptable. In order to be included in the conference programme at least one author must have registered and paid the appropriate fee.

Abstract submission: 30 September 2007
Notification of acceptance: 15 October 2007

Colleagues interested in organising invited sessions should contact the organising committee at mcdm2008@esc.auckland.ac.nz as soon as possible.

Track on Evolutionary Multiobjective Optimisation

As part of the conference a special track on Evolutionary Multiobjective Optimisation (EMO) will be organised. EMO utilizes evolutionary computation techniques to determine/approximate Pareto optimal solutions and became very popular in recent years. Besides comparison and integration of EMO and MCDM, the track will also cover EMO algorithm developments, test problems, metrics and comparative studies for EMO as well as real-world and industrial applications of EMO algorithms. It is intended to deepen interactions and collaborations of EMO and MCDM.

The EMO track is organized by Boris Naujoks, University of Dortmund, Germany. For more information contact boris.naujoks@uni-dortmund.de

Proceedings Volume

Springer will publish a proceedings volume in the "Lecture Notes in Economics and Mathematical Systems". A call for full papers will be published on the conference website.

Registration

Registration is solely via the conference website and is now available. Full registration includes a 2 year electronic subscription to the Journal of Multi-Criteria Decision Analysis published by Wiley (see http://www.wiley.com/WileyCDA/WileyTitle/productCd-MCDA.html for more information on the journal) and free membership in the MCDM society.

Meetings Calendar

New Zealand

42nd Annual Conference of the Operational Research Society of New Zealand
Auckland, New Zealand, 29 – 30 November 2007
www.onference.orsnz.org.nz

19th International Conference on Multicriteria Decision Making
Auckland, New Zealand, 7 – 12 January 2008
www.mcdm2008.orsnz.org.nz

Asia Pacific

5th International Conference on Business Process Management
Brisbane, Australia, 25 – 27 September, 2007
http://bpm07.fit.qut.edu.au/

IEEE Congress on Evolutionary Computation (CEC)
Singapore, 25 – 27 September, 2007
http://www.cec2007.org/

Eighth Int. Conf. on Operations and Quantitative Management
Bangkok, Thailand, 17 – 20 October, 2007
http://www.infoms.net/icoqm8

INFORMS Annual Meeting
Seattle, USA, 4 – 7 November, 2007
http://meetings.informs.org/Seattle07

19th National Conference of the Australian Society for Operations Research
Melbourne, 3 – 5 December, 2007
http://www.asor.org.au/new_conference.aspx

International

ICCOPT II & MOPTA07 Second International Conference on Continuous Optimization and Modeling and Optimization: Theory and Applications
Hamilton, Canada, 13 – 16 August 2007
http://iccopt-mopta.mcmaster.ca/

11th Conference on Stochastic Programming (SPXI)
Vienna, Austria 27 – 31 August 2007
http://www.spxi.org/

Operations Research 2007
Saarbruecken, Germany, 5 – 7 September 2007
http://www.or2007.de

Hamburg International Conference of Logistics 2007 (HICL2007)
Hamburg, Germany, 6 – 7 September, 2007
http://www.hicl.org/

EUROSIM 2007
Ljubljana, Slovenia, 9 – 13 September, 2007
http://www.eurosim2007.org

Fifth Annual International Symposium on Supply Chain Management
Toronto, Canada, 17 – 19 October, 2007
http://www.scmsymposium.org/

The 7th International Conference on Optimization: Techniques and Application: ICOTA
Kobe, Japan 12—15 December 2007-02-14
http://www.iict.konan-u.ac.jp/ICOTA7/index.html

See also http://meetings.informs.org/ for extensive listings of conferences.

Officers of the Operational Research Society of New Zealand 2007

President
David Ryan
Department of Engineering Science
The University of Auckland
Private Bag 92019, Auckland
Phone: 64 (9) 373 7599 x 88398
Fax: 64 (9) 373 7468
d.ryan@auckland.ac.nz

Vice President, Web Master
Andrew Mason
Department of Engineering Science
The University of Auckland
Private Bag 92019, Auckland
Phone: 64 (9) 373 7599 x 87909
Fax: 64 (9) 373 7468
a.mason@auckland.ac.nz

Treasurer
John Paynter
ISOM
The University of Auckland
Private Bag 92019, Auckland
Phone: 64 (9) 373 7599 x 87385
Fax: 64 (9) 373 7430
j.paynter@auckland.ac.nz

Secretary
Hamish Waterer
Department of Engineering Science
The University of Auckland
Private Bag 92019, Auckland
Phone: 64 (9) 373 7599 x 83014
Fax: 64 (9) 373 7468
h.waterer@auckland.ac.nz

Council Members
Matthias Ehrgott
(**Newsletter Editor**)
Department of Engineering Science
The University of Auckland
Private Bag 92019, Auckland
Phone: 64 (9) 373 7599 x 82421
Fax: 64 (9) 373 7468
m.ehrgott@auckland.ac.nz

Michael O'Sullivan jr.
Department of Engineering Science
The University of Auckland
Private Bag 92019, Auckland
Phone: 64 (9) 373 7599 x 87907
Fax: 64 (9) 373 7468
michael.osullivan@auckland.ac.nz

Alastair McNaughton
Department of Statistics
The University of Auckland Private Bag 92019, Auckland
Phone: 64 (9) 373 7599 x 85244
Fax: 64 (9) 308 2377
a.mcnaughton@auckland.ac.nz

Chuda Basnet
Department of Management Systems
The University of Waikato
Private Bag 3105, Hamilton
Phone: 64 (7) 838 4562
Fax: 64 (7) 838 4270
chuda@waikato.ac.nz

Ross James
Department of Management
The University of Canterbury
Private Bag 4800, Christchurch
Phone: 64 (3) 364 2987 x 7015
Fax: 64 (3) 364 2020
ross.james@canterbury.ac.nz

Tom Halliburton
Energy Modeling Consultants Ltd
95 Wyndham Rd
Pinehaven
Upper Hutt
Phone +64 4 972 9138
Fax +64 4 972 9139
tom.halliburton@attglobal.net

Fernando Beltran
ISOM
The University of Auckland
Private Bag 92019, Auckland
Phone: 64 (9) 373 7599 x 87850
Fax: 64 (9) 373 7430
f.beltran@auckland.ac.nz

Stefanka Chukova
School of Mathematics, Statistics and Computer Science
Victoria University of Wellington
PO Box 600, Wellington
Phone: 64 (4) 463 6786
Fax: 64 (4) 463 5045
schukova@mcs.vuw.ac.nz

Vicky Mabin
(**APORS/IFORS Rep**)
Victoria Management School
Victoria University of Wellington
P.O. Box 600, Wellington
Phone: 64 (4) 463 5140
Fax: 64 (4) 463 5253
vicky.mabin@vuw.ac.nz

Golbon Zakeri
Department of Engineering Science
The University of Auckland
Private Bag 92019, Auckland
Phone: 64 (9) 373 7599 x 84613
Fax: 64 (9) 373 7468
g.zakeri@auckland.ac.nz

Nicola Petty
Dept. of Management
The University of Canterbury
Private Bag 4800, Christchurch
Phone: 64 (3) 364 2190
Fax: 64 (3) 364 2020
nicola.petty@canterbury.ac.nz

Branch Chairs
Andy Philpott (Auckland)
Department of Engineering Science
The University of Auckland
Private Bag 92019, Auckland
Phone: 64 (9) 373 7599 x 88394
Fax: 64 (9) 373 7468
a.philpott@auckland.ac.nz

Vicky Mabin (Wellington)
Victoria Management School
Victoria University of Wellington
P.O. Box 600, Wellington
Phone: 64 (4) 463 5140
Fax: 64 (4) 463 5253
vicky.mabin@vuw.ac.nz

Shane Dye (Christchurch)
Department of Management
University of Canterbury
Private Bag 4800, Christchurch
Phone: 64 (3) 364 2886
Fax: 64 (3) 364 2020.
shane.dye@canterbury.ac.nz

The ORSNZ web site is http://www.orsnz.org.nz. Email contact: secretary@orsnz.org.nz.

To apply for membership or buy subscriptions, see the application form on our web site, and mail it to: Membership Secretary, ORSNZ, PO Box 6544, Wellesley Street, Auckland, NZ.

Get Your Free Forecast Pro Kit!

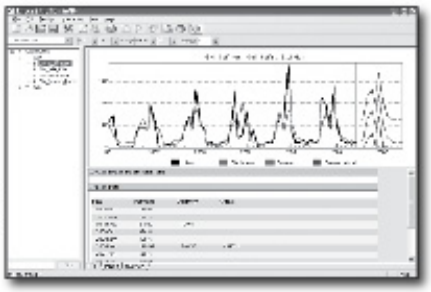
Use Forecast Pro to Forecast Sales & Resource Needs

HRS
Hoare Research Software Ltd

Forecast Pro XE Version 5 and Forecast Pro Basic Version 5 will make your forecasting easier and more accurate. Here's just a sample of what you'll find in V5:

Improved Expert Selection for more accurate automatic forecasting. Expert Selection now chooses from a broader range of models, more accurately detects seasonality in low-volume data sets and includes improved "special handling" for anomalous data sets.

A brand new, intuitive interface lets you view and interpret your data more easily and navigate effortlessly through large data sets and multi-level product hierarchies.



View your forecast by geographic region or branches.

Powerful new graphing and reporting capabilities allow you to create dazzling, presentation-quality reports in seconds. Version 5 includes four professionally-designed standardised report formats in addition to a custom reporting option for maximum flexibility.

Seasonal Simplification, **a powerful new *must-have* methodology** if you are forecasting data with more than 12 observations per year. Seasonal Simplification reduces the number of seasonal indexes used to model the data and often substantially improves forecast accuracy.

Complete the card and return it today to get your FREE Forecast Pro Info Kit!

A **streamlined regression modelling** facility with **enhanced diagnostics** that will save you time and improve your models. Using the new navigator-based modelling options, you can add and delete terms from your current model with a click of the mouse.

Five Ways to obtain your FREE Forecast Pro info kit:
1. Call 0800 477 776 or 07 839 9102 **2. Fax** the card to 07 839 9103
3. Visit www.hrs.co.nz/1876.aspx **4. Email** 1876@hrs.co.nz
5. Mail a copy of the form back completed below to: HRS, PO Box 4153, Hamilton East. **Note:** Please ask for your FREE Forecast Pro information kit and quote lead reference **1876** when contacting us.

ForecastPRO

Contact Details

Name:_____
Position:_____
Department:_____
Organisation:_____
Address 1:_____
Address 2:_____
City:_____
Phone:_____
Fax:_____
Email:_____
Your industry:_____
Your particular interest:_____
_____
_____

Yes - Please send me a FREE Info Kit that includes:

☐ **Forecast Pro**

ForecastPRO

☐ **The HRS Software Guide**

HRS
Hoare Research Software Ltd

1876 ***New Zealand's Technical Software Source***