NEWSLETTER

Operational Research Society of New Zealand

FEBRUARY 1970 VOL. 5 NO. 2.

INTERNATIONAL FEDERATION OF OPERATIONAL RESEARCH SOCIETIES

The Operational Research Society of New Zealand (Inc.) has just been admitted to I.F.O.R.S. as the result of a ballot held amongst I.F.O.R.S. member societies.

This is a very significant event in the development of the Society.

A vote of thanks to Professor Fraser Jackson who did the work leading up to the Society's admission, was carried by acclamation by Council.

COURSES INCLUDING O.R. TO BE HELD IN 1970.

This List has been compiled from information received from members in response to a request last year. There may be other courses of which we have not heard.

AUCKLAND

Economics II (a) Managerial Economics. Part of this paper is an elementary introduction to OR techniques of linear programming, capital budgeting, inventory control, replacement models and decision theory.
(Mr V.B. Hall, Mr A. MacCormick).

Economics III (a) Managerial Economics. From 1970 this paper will be entirely devoted to topics in O.R.
(Mr A. MacCormick).

Economics for M.A., M Comm. and Hons.

(a) Managerial Economics. Advanced topics in O.R., especially non-linear and dynamic programming and stochastic inventory theory.
(Professor A.R. Bergstrom , Mr A. MacCormick)

CHRISTCHURCH

Systems Engineering - D.G. Elms Feb. 23 to May 1.

Engineering Operations and Economics - F.P.S. Lu May 25 to Aug. 7.

These are both graduate-level courses given by the Department of Civil Engineering. Each lasts about 10 weeks with a course content of 3 lectures/week.

WELLINGTON

Operations Research - G.A. Vignaux, P. König

Simulation - G.A. Vignaux

Both graduate level courses given by the Department of Information Science (46040 Ext. 514). Each consists of about 3 lectures/week throughout the Academic year.

Operations Research Techniques - G.A. Vignaux

Part of the 'Executive Development Program' given by the Department of University Extension, Victoria University of Wellington, aimed at the technically trained executive. 8 evening meetings starting, May 26, 1970.

MINUTES OF SPECIAL GENERAL MEETING OF OPERATIONAL RESEARCH SOCIETY HELD AT 7.30p.m. THURSDAY 20 NOVEMBER AT MANCHESTER UNITY BLDG, LAMBTON QUAY, WELLINGTON

Present: 13 members.

Apologies: Mr Kimble
Dr Foster
Mr O'Brien

Business: It was proposed (Vignaux/Kirkham) that clause 4c of the constitution which allows for the biennial retirement of Council members (inter alia) should be replaced by

> "The members of the Council shall retire annually, but shall be available for re-election".

Carried.

The meeting closed at 7.35p.m.

MINUTES OF ANNUAL GENERAL MEETING OF OPERATIONAL RESEARCH SOCIETY HELD AT 7.35p.m. THURSDAY 20 NOVEMBER AT MANCHESTER UNITY BLDG, LAMBTON QUAY, WELLINGTON

Present: 26 members

1. Apologies: Mr Kimble
   Dr Foster
   Mr O'Brien
   It was agreed (Jackson/Latimer) that these should be sustained.

2. Minutes of last A.G.M.

   It was agreed that these were a correct record of the proceedings (Latimer/Campbell).

3. Matters Arising

   Left to other parts of meeting.

4. President's Report

   It was seen as a year of progress. The report was adopted (Vignaux/Wallace).

5. Treasurer's Report & Financial Statement

   (a) Newsletter. Extra expenses on the expansion of the newsletter were well justified. A suggestion to further advance to a covered publication (like the Statistical Association's journal) and multi-lithed pages was not favoured on the grounds of cost.

   (b) Cocktail Party Loss. A general guideline was proposed that we should try to break-even, but not get upset if we do make a loss.

   (c) Venue of Annual Conference. Do we follow the Statistical Association to Palmerston North or remain in Wellington? It was agreed (Major/Evans) that we have a poll as soon as the results of the Statistical Association poll is known.

(d) Overdue Subscriptions. It was agreed (Latimer/Wallace) that those whose subscription was 3 years' overdue should be removed from the list of members.

The report was adopted (Wallace/Campbell).

6. O.R. Society Lecture Prize ($20)

This was awarded to P. Konig for his talk in June on "positioning of radar stations for air defence using dynamic programming and a digital terrain model".

7. Election of Officers

President:	Prof. G.A. Vignaux	(Wallace/Campbell)
Vice-President:	Prof. L.F. Jackson	(Latimer/Bieleski)
Hon. Secretary:	Mr A.H. Milkop	(Campbell/Wallace)
Hon. Treasurer:	Mr A.R. Wallace	(Schroder/Kirkham)
Hon. Auditor:	Mr P.D. Hasselberg	(Wallace/Kirkham)

These being the sole nominations, they were declared elected.

Council Members: Successful nominees (in alphabetical order)

Mr H. Barr	(Milkop/Campbell)
Mr P. Bieleski	(Latimer/Evans)
Mr B.K. Campbell	(Bieleski/Wallace)
Mr D.C. Cook	(Jackson/Bieleski)
Mr B. Kaiser	(Wallace/Kirkham)
Mr D.J. O'Dea	(Milkop/Tate)
Mr R.C. Wheeler	(Kirkham/Wallace)

Unsuccessful nominees (in alphabetical order)

Mr E.A. Christiansen	(Campbell/Anderson)
Dr P.K. Foster	(Campbell/Bieleski)
Mr L.E. O'Brien	(Bieleski/Christiansen)
Mr C.W. Walker	(Wallace/Bieleski)

8. Subscriptions:

On the motion of Wallace/Schroder it was agreed that subscriptions for the current financial year should be

Full members	$4	reducing to	$3	if paid within 6 months
Associate	$3	"	$2	" " "
Student	$1	"	50c	" " "

the reason for the increase in full members' subscriptions is that the Society expects to be joining the International Federation of Operational Research Societies shortly. Every full member will then be supplied with a regular copy of the "International Abstracts in O.R." (value $1.25).

9. General Business:

(a) Letterhead. The particular O.R. symbol was chosen as the arrows reflect a tension, and a choice between alternatives It was agreed that we should express our appreciation for the quality of the work.

(b) Bay-of-Plenty Branch: There are not enough members for a full O.R. Society branch, but there may be enough for a conglomerate of O.R./Computer/Work Study/Statistical Societies.

The A.G.M. finished at 8.30p.m.

A.H. Milkop
(Hon. Sec.)

G.A. Vignaux
(President)

O.R. IN THE MINING INDUSTRY

Most of the O.R. undertaken by the Mines Dept in N.Z. to date has been with respect to coal-mining. Coal-mining is carried out in 4 major fields in N.Z., of which 3 are in the South Island. They are the Waikato-Taranaki, Buller-Reefton, Grey Valley, and Otago-Southland fields.

A single production optimisation problem would determine what parts of the country should be supplied from each mine. However, the problem immediately degenerates because of the non-homogeneous nature of the various coals - namely calorific value, extent of coking, sulphur content, and consumer preference. These set narrower limits to the possible solutions. We therefore leave aside the overall approach, and examine individual problems.

1. Waikato:

There are 3 underground mines and 4 opencast mines in the Waikato. Demand varies according to the seasons, and Meremere electric power station demand. Supply can be from limited resources of opencast coal, or dearer underground coal. Output from opencast mines can be varied substantially during a year, whereas underground production is virtually fixed. We can draw up a very complex linear program which takes into account the production capability for each mine, its marginal cost of output, demand for the various-sized coals, the screening percentage at each mine (proportion of lump coal), dumping and lifting charges, and revenue from sales. A simplified version of the main model, which devides the year into several periods, provides a satisfactory approximation for some purposes. The model is used to help prevent any necessity for dumping surplus fine coals.

2. Strongman:

The Strongman mine in the Grey Valley, which uses about 100,000 tons p.a., was chosen to do a regression analysis of miner wage sheets to determine the implications of simpler wage payment procedures. At present a miner's pay can be made up of any of over 50 allowances, and generally 20 or so are included. These naturally lead to arguments both at fortnightly pays and national award agreements. An analysis was made of a stratified sample of mine wage sheets to see the effect of paying miners for far fewer items at different rates. Under any unmodified alternative scheme 50% would naturally be better off, and 50% worse off than at present. A major advantage of the scheme would be that it would offer a less variable wage to miners, but in so doing would remove some incentives or disincentives. We have been able to calculate the percentage by which all miner earnings would have to be increased to ensure that say 95% are better off over a year under the new system.

3. Buller:

The New Plymouth power station will require coal to be transported form Stockton (in the Buller) via Westport to New Plymouth. The main problem is to determine what proportions of underground coal and opencast coal should be mined in the light of uncertain demands caused by seasonal variations, rainfall fluctuations, and the long-term state of the electric supply system. This problem is made all the more complex by an unknown quantity (0 to ∞) of natural gas in the off-shore oil discovery off Opunake. Techniques used are discounted cashflows linear programming with built-in allowances to discount future demands and costs, and a simulation program. From these we have been able to determine the desirability of using fuel oil at later stages, maximum opencast overburden ratios to work to, maximum underground losts allowable, and the economics of using natural gas. Further work should yield optimum dump sizes, optimum rate of coal stripping, together with the maximum allowable level of coal stripped in advance.

Conclusion:

The closure of the Dobson Mine in the Grey Valley last year, together with a loss generated entirely in the South Island, and mainly on its West Coast, have led to an unduly poor public image for the whole industry. It is apparent that certain regions in the industry still have a vigorous future ahead of them, and planning is keyed to this.

CORRECTION TO LIST OF MEMBERS

As an appendix to the Annual Report, a list of members was supplied. The name F.P. Sihn should read F.P.S. Lu. We offer a sincere apology to Mr Lu for such a distortion.

RECENT ADVANCES IN FORECASTING

Notes for a talk given to a seminar at AMD on 28 November 1969

H.R. Thompson

This paper is a more or less up-to-date account of the gospel according to Box-Jenkins (B-J for short), based on their publications (1967 and 1968 particularly, see references) and on the experiences of a year I spent in Wisconsin in the close vicinity of the inimitable George Box, master of the aphorism or throwaway phrase (eg "some people still think, despite computers, that the object of statistics is to end up with fewer numbers than you started with") and also of practical and theoretical aspects of time series analysis and design and analysis of experiments. It is to be hoped that the long-awaited B-J book, Time Series Forecasting and Control (Holden-Day, latest date for publication Fall 1969!) will supplement and augment this account with more practical details than are in the papers already referred to.

B-J time series analysis is built round two basic types of model of a stationary process z_t recorded at equally spaced intervals of time, i.e. varying about a fixed mean μ and having the same probability structure throughout. These are the moving average (M.A.) and autoregressive (A.R.) models, and if we write $w_t = z_t - \mu$ for the deviations about the mean, the simplest representations are

MA(1) : $w_t = a_t - \theta a_{t-1}$

MA(2) : $w_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2}$

AR(1) : $w_t = \phi w_{t-1} + a_t$

AR(2) : $w_t = \phi_1 w_{t-1} + \phi_2 w_{t-2} + a_t$

where the a_t are uncorrelated random normal variables with mean zero and the same variance, and θ, ϕ are parameters characterizing the series. They must fall within certain ranges for the series to be stationary (invertibility). In the MA models the deviations are weighted averages of random normal variables whereas in AR models the present deviation is a weighted average of previous deviations plus an extraneous shock.

AR models can be expressed as infinite moving averages, and vice versa. For example, by substituting recursively for w on the RHS of AR(1) we get

$$w_t = a_t + \phi a_{t-1} + \phi^2 a_{t-2} + \text{--}$$

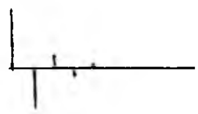
the effect of previous shocks dying out exponentially since $|\phi| < 1$ for stationarity.

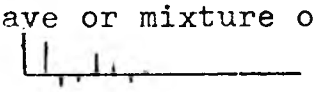
Stationary series are characterized by their autocorrelation function, and the theoretical autocorrelations ρ_k show characterist patterns for different models. For example,

MA(1) : $\rho_1 = -\theta/1+\theta^2$. All others zero

MA(2) : ρ_1 and ρ_2 non-zero 

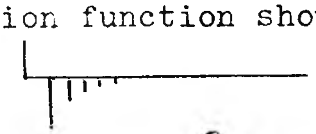
AR(1) : $\rho_k = \phi^k$ 

or  if $\phi < 0$

AR(2) : damped sine-wave or mixture of exponentials 

This model can produce pseudo periodicities in z_t.

A mixed autoregressive moving average (ARMA) representation is sometimes useful, since each is an infinitely long version of the other and a mixture makes for a saving in the number of parameters. Examples: ARMA(1,1) : $w_t = \phi w_{t-1} + a_t - \theta a_{t-1}$

The autocorrelation function shows AR behaviour after first lag correlation ρ_1 

ARMA(1,2) : $w_t = \phi w_{t-1} + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2}$, and so on.

Generally, in ARMA(p,q) it has been found that p,q $\leq$ 2 is sufficient to explain most stationary situations.

If a series is non-stationary, the B-J approach is simply to difference it until it is stationary. Non-stationarity in level can be fixed by taking first differences

$$\nabla z_t = z_t - z_{t-1}$$

and fitting ∇z_t to one of the models. Non-stationarity in level and slope is fixed by taking second differences

$$\nabla^2 z_t = z_t - 2z_{t-1} + z_{t-2}$$

The whole system can be described neatly in terms of the backward shift operator B, defined by $Bz_t = z_{t-1}$

$$\nabla z_t = (1-B)\, z_t$$
$$\nabla^d z_t = (1-B)^d\, z_t$$

$$a_t - \theta_1 a_{t-1} - \cdots - \theta_q a_{t-q} = (1-\theta_1 B - \cdots - \theta_q B^q)\, a_t = \theta_q(B)\, a_t$$

$$z_t - \phi z_{t-1} - \cdots - \phi_p z_{t-p} = (1-\phi_1 B - \cdots - \phi_p B^p)\, z_t = \phi_p(B)\, z_t$$

So generally, for a situation where the dth difference of z_t can be represented by a mixed ARMA model of order p in the AR part and q in the MA part, we write

$$\phi_p(B)\ (1-B)^d\ z_t = \theta_0 + \theta_q(B) a_t$$

where $\theta_0 = (1-\phi_1 - \cdots - \phi_p)\mu$ and is usually zero if $d > 0$.

The model is essentially a device for transforming the correlated series z_t to a series of uncorrelated normal deviates or "white noise", in which case, to quote Box, "all the goody has been extracted from the data".

The B-J approach to model-building is an iterative one, with the following stages:

(1) <u>identification</u> (via autocorrelation function)
(2) <u>fitting</u> (estimation of parameters)
(3) <u>diagnostic checking</u> (goodness of fit of model)
(4) <u>refitting and rechecking</u> until a satisfactory representation is found, and
(5) recycling to (1) as more information comes to hand.

<u>Identification</u>

(i) Calculate autocorrelation functions for z_t, ∇z_t, $\nabla^2 z_t$.

(ii) Select d for which sample autocorrelations r_k damp out fairly quickly. Continued high autocorrelations for large k is an indication of non-stationarity.

(iii) Select model by matching pattern of r_k to the ρ_k of a suitable model.

Note that in short series, sampling errors will be large and undue emphasis may be placed on r_k that are high by chance. For a series of 50 observations, 1 autocorrelation in 10 will be expected to be greater in magnitude than 0.23, even if the series is only white noise, and standard errors may be appreciably higher for the models above, depending on the values of the parameters.

Fitting

(i) Initial values of parameters are obtained by equating sample autocorrelations to the first p+q theoretical values for the chosen model, or by educated guesses.

(ii) Efficient estimates of the parameters are obtained by maximum likelihood, or equivalently under the assumption of normally distributed errors, least squares, i.e. minimising.

$$\sum a_t^2 = S(\underset{\sim}{\phi}, \underset{\sim}{\theta})$$

If the model is $\phi(B)\ w_t = \theta(B)\ a_t \quad (w_t = \nabla^d z_t)$ then formally

$$a_t = \theta^{-1}(B)\,\phi(B)\ w_t$$

and we can calculate the a_t recursively, given a few starting values for a and z whose effect can be ignored in a reasonably large series. The minimum S is found by examining its behaviour for a grid of values of the parameters, especially in cases where their total number does not exceed 2.

Otherwise, in more complicated cases, we can minimise for one or more parameters conditional on the values of others by means of the contours of the conditional sum of squares, or use non-linear least squares; an iterative method which, hopefully, converges to the correct solution.

Diagnostic checking

If the model is all right, then the observed deviations $\hat{a}_t$ from the model with the best parameter values inserted should be random normal deviates (or very nearly).

Tests for this are:

(i) Compare autocorrelation function of the $\hat{a}_t$ with the theoretical of $\rho_i = 0,\ i > 0$, S.E.$(r_i) \simeq \sqrt{\frac{1}{n}}$. An overall test of the above is given by the statistic $n\sum_1^n r_k^2$, which is distributed as χ^2 with n-p-q degrees of freedom under the null hypothesis.

(ii) Overfitting. Fit a model which is more complicated (in a sensible direction) and see if a better fit is possible. The reduction in the error sum of squares due to fitting the extra parameter(s) can be tested using the F statistic.

Incorporation of seasonal effects in the model

Economic time-series in particular often have a periodic structure with known period s. For example s = 4 for quarterly data with a yearly period. The general model can accommodate this behaviour without much trouble (mathematically, that is!)

B-J derive the seasonal model as a two-stage process, as follows:

(a) the points at a given position in the period, say $z_t, z_{t-s}, z_{t-2s}, \ldots$, being free of seasonality effects, can be fitted by one of the previous models. If they have to be differenced to get stationarity we fit $w_t = (1-B^s)^D z_t$ [note that $\nabla_s z_t = z_t - z_{t-s} = (1-B^s)\, z_t$] with residuals e_t by a model

$$\Phi_P(B^s)\, w_t = \Theta_Q(B^s)\, e_t,$$

it being assumed that the same model applies for all positions in the cycle.

(b) the residuals e_t from (a) will still be locally dependent on each other, and so another model is fitted to these "seasonal-free" residuals;

$$\phi_p(B)\,(1-B)^d\, e_t = \theta_q(B)\, a_t$$

where now the a_t are white noise
Eliminating e_t, we get

$$\phi_p(B)\, \Phi_P(B^s)\,(1-B)^d\,(1-B^s)^D\, z_t = \theta_q(B)\,\Theta_Q(B^s)\, a_t$$

In practice, however, identification, fitting and checking the model seem to be done as a single stage process, analysing directly the variable

$$w_t = (1-B)^d\,(1-B^s)^D\, z_t$$

Sufficient differencing is done so that w_t has a fairly simple autocorrelation function, but there remains the problem that with the greater multiplicity of models possible identification can be much more difficult, especially if sampling errors are high.

Dynamic models

Dynamic models are those in which one series is used to predict (or control) another. The aim is to reduce forecasting errors and in this respect the idea is similar to covariance. As examples, consider some measurement x_t on the input to an industrial process (eg. impurities in steel) which affects the output y_t, or the sales of camera film x_t which affect the later film processing load y_t. If there is a reasonable lag in the response of y_t to x_t we have a useful means of forecasting y_t further in advance with greater precision. In economic parlance x_t is a "leading indicator".

The model is described by means of the transfer function, or impulse response function (I.R.F.) which specifies the effect of one series on the other. For example, with simple exponential weighting we might have $y_t = wx_t + \phi wx_{t-1} + \phi^2 wx_{t-2} + \cdots + a_t$, in which case

$$y_t = \phi y_{t-1} + wx_t + a_t - \phi a_{t-1}$$

The parameters ϕ and w can be solved for by getting contours of $\sum a_t^2$ over a grid of ϕ and w.

In terms of the backward shift operator B,

$$y_t = \frac{w}{1-\phi B} x_t + a_t$$

if there is a delay of p steps,

$$y_t = \frac{w B^p}{1-\phi B} x_t + a_t$$

If the delay period is fractional, w is replaced by $w_0 + w_1 B$, $(w_0 + w_1 = 1)$.

Generally,

$$y_t = v_0 x_t + v_1 x_{t-1} + \cdots + v_k x_{t-k} + n_t$$

$$= v(B) x_t + n_t$$

where the weights v applied to previous inputs define the I.R.F. v(B) and the n_t are correlated noise. This is not the best way of describing the model as there are too many parameters (it is not parsimonious), so in line with the previous approach for a single series we difference both series until they are stationary, but in addition use the cross correlation function also. Parsimony leads to a relation of the form

$$\delta(B)\, y_t = w(B)\, x_t + n_t$$

where the δ and w functions might also include differencing. Explaining the noise n_t in terms of white noise a_t by an ARMA model of the form

$$\phi(B)\, n_t = \theta(B)\, a_t$$

and eliminating n_t,

$$\phi(B)\,\delta(B)\, y_t = \phi(B)\, w(B)\, x_t + \theta(B)\, a_t$$

or formally

$$a_t = \theta^{-1}(B)\,\phi(B)\,\delta(B)\, y_t - \theta^{-1}(B)\,\phi(B)\, w(B)\, x_t$$

which is the model, i.e. having transformed the observations into white noise, we have explained all there is to explain in the data!

As with the seasonal model, however, the apparent ease of the mathematical derivation obscures to some extent the practical details. Considerable experience appears to be needed for the identification and fitting of these models. As yet we lack this experience but are trying to repair the omission, and hope at some later date to be able to report on the success (or lack of it) which attends our efforts.

References

Box, G.E.P., Jenkins, G.M. (1968). Some recent advances in forecasting and control. Applied Statistics, 17, 91-109.

Box, G.E.P., Jenkins, G.M., Bacon, D.W. (1967). Models for forecasting seasonal and non-seasonal time series, pp. 271-311 of 'Advanced Seminar on Spectral Analysis of Time Series', Ed. B. Harris (Wiley).

NEW MEMBERS

Brief details of recently accepted members:-

ERNEST A. COTTINGHAM M.Sc.
Scientific Programmer, Finance and Accounts Branch,
New Zealand Railways.

JOHN A. HARRAWAY B.Sc (Hons), M.Sc.
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Miss PRUE HYMAN M.A. (Oxon)
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University of Canterbury, P.B.,
CHRISTCHURCH.

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