NEWSLETTER

Operational Research Society of New Zealand

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RISK ESTIMATES IN PROJECT EVALUATION

A.T.G. McArthur

Introduction

Project evaluation has become an essential part of decision making in marketing as in other areas of economic and social life. However in estimating the value of a project, it is usual to assume that it is possible to estimate with certainty the cash flows resulting from the adoption of a project. This assumption considerably limits the usefulness of a project evaluation because in reality there is usually considerable risk associated with the estimation of cash flows. One risky project may have a higher value under the assumption of certainty than another safer project. In choosing between them, the adoption of the risky project may place the firm in a position from which it will be hard to recover. Assuming certainty could lead to disastrous results.

There is now an increasing interest in project evaluation which takes risk and uncertainty into account.[1] In assessing the value of a project under risk three pieces of information are needed:

1. An estimate of the expected value of the project.
2. An estimate of the variance of the value of the project.
3. A probability distribution.

With the aid of this information it is possible to estimate the probability of the firm jeopardising its future position by adopting a risky project. Expected gains and risks can be balanced in deciding whether or not to adopt the project.

In making these estimates, there are two alternative approaches - the analytical method and the Monte Carlo method. In some complex situations it may be necessary to use Monte Carlo simulation in which repeated simulation runs of the project are made under a computer simulated stochastic environment. The procedure has the advantage that the model of the project can be extremely complex. It can include interaction of random variables and decision rules over time. Simulation is particularly useful when project results in one year have effects on results and decisions in subsequent years. Pessesier (1966) recommends this procedure for new product decisions and Cohen and Elton (1967) have used simulation for portfolio analysis.

Analytical methods are available for calculating the variance of a project (see Murphy (1968) for instance) and this paper introduces a simplified procedure for estimating both the variance of the present value and the future value of a project. The method involves making some assumptions which may or may not seem warranted in particular cases but the simplicity of the method gives it a considerable practical advantage.

Present Value and its Variance

The method of estimating the value of projects in which allowance is made for time by using compound interest formulae are well known. The estimation is termed the present value.[2]

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First estimates are made of the cash flow in each year resulting from adopting the project. A negative cash flow is a flow of cash from the firm to the project, and a positive flow occurs when cash flows from the project to the firm.

$$a_o, a_1, \ldots, a_i, \ldots a_n$$

are a set of cash flows associated with a project with a life of n years. a_o is the cash flow now, as a result of adopting the project, a_1 is the cash flow at the end of the first year of operations etc.

To measure the influence of delay on value, the discounting formula $1/(1+R)^i$ is used to transform future cash flows to an equivalent present value. The present value formula is

$$P = a_o + \sum_{i=1}^{n} a_i/(1+R)^i \qquad (1)$$

where R is the rate of interest expressed as a proportion and P is the present value.

The expected value of the present value is written

$$Exp(P) + \bar{a}_o + \sum_{i=1}^{n} \bar{a}_i /(1+R)^i \qquad (2)$$

where $\bar{a}_i$ are the mean cash flows in each year.

In this paper, it is assumed that the cash flow now a_o is known with certainty and is a constant. It can therefore be left out of the variance calculations.

The variance of the present value if calculated by the formula,[3]

$$Var(P) = \sum_{i}^{n} \sum_{j}^{n} \frac{1}{(1+R)^i} \cdot \frac{1}{(1+R)^j} r_{ij} \sigma_i \sigma_j, \qquad (3)$$

where σ_i and σ_j are standard deviations of the cash flow in the i^{th} and j^{th} year respectively and r_{ij} is the correlation coefficient between cash flow in the i^{th} and j^{th} years. If $i=j$, $r_{ij}=1$ and $\sigma_i = \sigma_j$ and $r_{ij}\ \sigma_i\ \sigma_j$ equals the variance of cash flow. If $i \neq j$, $r_{ij}\sigma_i\ \sigma_j$ is the covariance between cash flow in the i^{th} and j^{th} years.

Equation (3) can be simplified by making three assumptions.

Assumption 1.

"That the standard deviation of the cash flow is the same in all years."
$\sigma_1 = \sigma_2 = \sigma_i = \sigma_n = \sigma$.

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Equation (3) now becomes

$$\mathrm{Var}(P) = \sigma^2 \sum_{i}^{n} \sum_{j}^{n} \frac{1}{(1+R)^i} \frac{1}{(1+R)^j} r_{ij} \tag{4}$$

Assumption 2.

"That the correlation coefficients between cash flows in successive years are all equal."

$$r_{i,\,i+1} = r.$$

This assumption in conjunction with Assumption 3 leads to considerable practical simplifications of equation 3.

Assumption 3.

"That between two successive years, the variation in cash flow in the i^{th} year causes variation in the cash flow in the $(i+1)^{th}$ year and that all other causes of variation in the $(i+1)^{th}$ year are independent of the cash flow in the i^{th} year. These two causes of variation in cash flow in the $(i+1)^{th}$ year are additive."

Consider cash flows over several years termed A, B, C,..... . Cash flow variation in year A causes cash flow variation in year B which causes variation in year C etc. Also consider factors a, b, c, etc. Factor a causes all the remaining variation in cash flow in year B and is independent of cash income in year A. Factor b causes all the remaining variations in each flow in year C and is independent of cash flow in year B. Diagram 1 shows the causal pattern for cash flow in year B.

Diagram 1.

Now since cash flow in year B is caused by cash flow in year A, and factor a acting additively,

$$B = A + a,$$

and

$$\bar{B} = \bar{A} + \bar{a} \;.$$

The covariance between B and A is

$$E(B-\bar{B})(A-\bar{A}) = E(((A-\bar{A}) + (a-\bar{a}))(A-\bar{A}))$$
$$= E(A-\bar{A})^2 + E(a-\bar{a})(A-\bar{A})$$

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As A and a are independent, the last term of the equation above equals zero.

$$\therefore \quad COV(B,A) = \sigma^2_A \ .$$

$$r_{BA} = COV(B,A)/\ \sigma_B\ \sigma_A = \sigma^2_A/\ \sigma_B\ \sigma_A$$

$$= \sigma_A/\ \sigma_B,$$

and $$r^2_{BA} = \sigma^2_A/\ \sigma^2_B \ .$$

Similarly $$r_{Ba} = \sigma_a\ /\ \sigma_B,$$

and $$r^2_{Ba} = \sigma_a^2/\ \sigma_B^2.$$

Because $$\sigma_B^2 = \sigma_A^2 + \sigma_a^2,$$

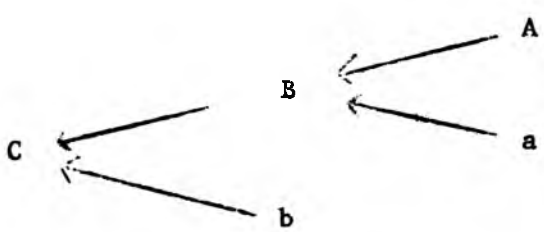
then $$\sigma_A^2/\sigma_B^2 + \sigma_a^2/\ \sigma_B^2 = 1 \ ,$$

and $$r^2_{BA} + r^2_{Ba} = 1.$$

r^2_{BA} is the coefficient of determination of B by cause A. This index is that fraction of complete determination of B for which A is directly responsible.

In diagram 2 cash flow in year C is caused by cash income in year B and this in turn is caused by cash flows in year A with other independent factors being shown by lower case symbols.

Diagram 2.



$$C = B + b \quad \text{and} \quad B = A + a.$$

$$C = b + a + A.$$

..../

$$\sigma_C^2 = \sigma_B^2 + \sigma_b^2 \quad \text{and} \quad \sigma_B^2 = \sigma_A^2 + \sigma_a^2$$

$$\therefore \quad \sigma_C^2 = \sigma_b^2 + \sigma_a^2 + \sigma_A^2 \ .$$

Also $\quad r_{CB}^2 = \sigma_B^2 / \sigma_C^2, \ r_{BA}^2 = \sigma_A^2/\sigma_B^2$, and $r_{CA}^2 = \sigma_A^2/\sigma_C^2$.

Because the fraction of the variation of B caused by variation in A is r_{BA}^2 and the fraction of the variation in D caused by variation in B is r_{CB}^2, the fraction of variation in C caused by A is

$$r_{CA}^2 = r_{CB}^2 \cdot r_{BA}^2$$

$$\therefore \quad r_{CA} = r_{CB} \cdot r_{BA} \ .$$

This is called the chain rule in the theory of path coefficients.[4]

Under Assumption 2, all correlation coefficients are equal to r. Therefore the correlation between the cash income in the i^{th} and $(i+2)^{th}$ year will be r^2. As equation (5) can be easily generalised to a chain of n cash incomes, the correlation between the cash income in the i^{th} year and the income n years hence, the $(i+n)^{th}$ year, will be r^n. This is shown for n = 3 in Diagram 3.

Diagram 3.

$$\begin{tikzcd}
a_i \arrow[r, "r"] \arrow[rr, bend left=40, "r^2"] \arrow[rrr, bend right=40, "r^3"'] & a_{i+1} \arrow[r, "r"] \arrow[rr, bend left=40, "r^2"] & a_{i+2} \arrow[r, "r"] & a_{i+3}
\end{tikzcd}$$

By using the three assumptions and equation (2) now becomes.

$$\mathrm{Var}(P) = \sigma^2 \sum_{i}^{n} \sum_{j}^{n} \frac{1}{(1+R)^i} \cdot \frac{1}{(1+R)^j} \cdot r^{|i-j|} \qquad (6)$$

with r^0 being defined as 1 when r = 0.

Future Value and its variance.

As well as calculating present value the future value at the termination of the project (after n years) is a useful method of valuing projects when all projects have the same life. However estimating the future value of the project after m years (where $m \leq n$) can also be useful in determining how many years it takes before the initial negative cash flows plus interest are balanced by the positive cash flows. This number of years is the payback period for projects

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which start with negative a_i's which become positive thereafter. With estimates of the expected future value, the variance of the future value, and with a probability distribution it is possible to give probability estimates of the future value of the project after various numbers of years have elapsed since the project started.

The formula for the future value after m years is

$$S_m = a_0 (1+R)^m + a_1 (1+R)^{m-1} + \dots + a_m$$

$$= a_o (1+R)^m + \sum_{i=1}^{m} a_i (1+R)^{m-i} \qquad (7)$$

The expected future value is

$$Exp(S_m) = \bar{a}_o (1+R)^m + \sum_{i=1}^{m} \bar{a}_i (1+R)^{m-i} \qquad (8)$$

where mean cash flow $\bar{a}_0$ has been separated from the summation indicating that because its value is known with certainty it will not be included in the variance calculation.

$$Var(S_m) = \sum_{i}^{m} \sum_{j}^{m} (1+R)^{m-i} \cdot (1+R)^{m-j} \cdot r_{ij} \sigma_i \sigma_j \qquad (9)$$

Making assumptions 1, 2, and 3 above equation (9) becomes

$$Var(S_m) = \sigma^2 \sum_{i}^{m} \sum_{j}^{m} (1+R)^{m-i} \cdot (1+R)^{m-j} \cdot r^{|i-j|} \qquad (10)$$

<u>Method Use</u>

The parameters of equations (6) and (10) have been termed the present value variance factors and the future value variance factors respectively.

For example a marketing project with a life of five years might have these expected cash flows,

$\bar{a}_0$ = -\$1,000

$\bar{a}_1$ = \$ 300

$\bar{a}_2$ = \$ 380

$\bar{a}_3$ = \$1,000

$\bar{a}_4$ = \$1,000

$\bar{a}_5$ = \$ 500

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If the firm uses a 10 per cent rate of interest in its project evaluation analysis, then the expected present value of this project is

$$\text{Exp(P)} = -1000 + \frac{300}{(1+.1)} + \frac{800}{(1+.1)^2} + \cdots + \frac{500}{(1+.1)^5}$$

$$= \$1{,}745$$

To estimate the variance of the present value it is necessary to assume that the variances for each cash flow are all equal in the firm through to the fifth year. (If this assumption seems unwarranted then it is necessary to use equation (3) to estimate the variance of present value perhaps using the relationship given in Diagram 3 to calculate the cross correlations (r_{ij}) if it is assumed that the correlation between successive cash flows are constant.)

If the equal variance assumptions are accepted, then executives can be asked to focus on, say, year 3. Let us say they could accept "even money" that the cash flow in year 3 will fall within \$1000 ± 200. Assuming that cash flows are normally distributed this can be transformed with an estimate of variance. Fifty percent of the area under a normal curve falls within $\mu \pm 0.67\sigma$. Hence our estimate of the standard deviation in this case is $200/0.67 \simeq \$300$.

The correlation coefficient is assumed to be equal between successive cash flows for this method. (If this assumption is unwarranted, a return to equation (3) is necessary, using the chain rule of equation (5) to calculate the cross correlations r_{ij}.) Taking two successive years it is necessary to estimate the regression of the second year on the first. In this case the regression coefficient will be equal to the correlation coefficient because it has been assumed that the variance of cash flows are all equal. The following questionnaire for our example can aid in estimating the regression of the cash flow in year 5 or the cash flow in year 4.

"Give your estimate for the cash flow in year 5 given that the cash flows below occurred in year 4.

Cash flow in Year 4.	Your estimate for Year 5.
\$ 600	\$______
\$ 800	\$______
\$1,000	\$1,000
\$1,200	\$______
\$1,400	\$______

If these estimates for year 5 were 800, 900, 1000, 1100 and 1200, then the estimates of the regression would be 0.5. (High estimates of this regression would warn the analyst against the assumption of equal variance for cash flows.)

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In this example we have,

$$r = 0.5$$
$$R = 0.1$$
$$n = 5$$

The appropriate present value variance factor is 6.446 . Thus

$$\text{Var}(P) = 300^2 \ . \ 6.446$$

$$= 58 \times 10^4$$

$$\text{SD}(P) = \sqrt{58 \times 10^4}$$

$$= \$760$$

Because the present value is a linear combination of random variables its distribution will be normal.

There is only a 5 per cent chance that the present value will be less than $491 given the estimate which have been used and the assumptions made.

Examination shows that the present value variance factors converge as the life of the project, n, increases. When the project is assumed to have an infinite life the present value variance factor is:

$$\sum_{i}^{\infty} \sum_{j}^{\infty} (1+R)^{-i} (1+R)^{-j} r^{|i-j|}$$

This simplifies to:

$$\frac{1 + R + r}{[(1+R)^2-1] \ [1+R-r]}$$

. It can be used to calculate approximate present value variance factors for cases where n is high.

After a year the project has an expected value of -$800, it breaks even at the end of the second year and by the year 5 it has an expected future value of $2820.

The variance and standard deviation of the future value in each year can be calculated by multiplying the cash flow variance of 300^2 by the appropriate future value variance factor for an interest rate of 10 per cent and a correlation of 0.5.

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The expected future value of the project can be exhibited in the form demonstrated by Diagram 4. The upper and lower boundaries in this diagram indicate that 90 per cent of future values will fall within these limits.

Diagram 4 can be explained as follows. By the end of the second year (and excluding all cash flows thereafter) the project can be expected to have broken even, that is, it has an expected future value at year 2 of zero. However, in 90 per cent of cases the future value will fall within ±$900. While the expected future value is $1000 at year 3 the lower boundary is still negative. Hence there is still a chance that the project will not have broken even by this time. However by year 4 the lower boundary is positive so that in "95 per cent of cases" the project will have broken even by this time.

While the simplifying assumptions in using present value and future value variance factors may invalidate the method in some cases, these assumptions may prove a relatively small source of error in estimating the variance of present and future values compared with errors arising from estimating variances and covariances of cash flows.

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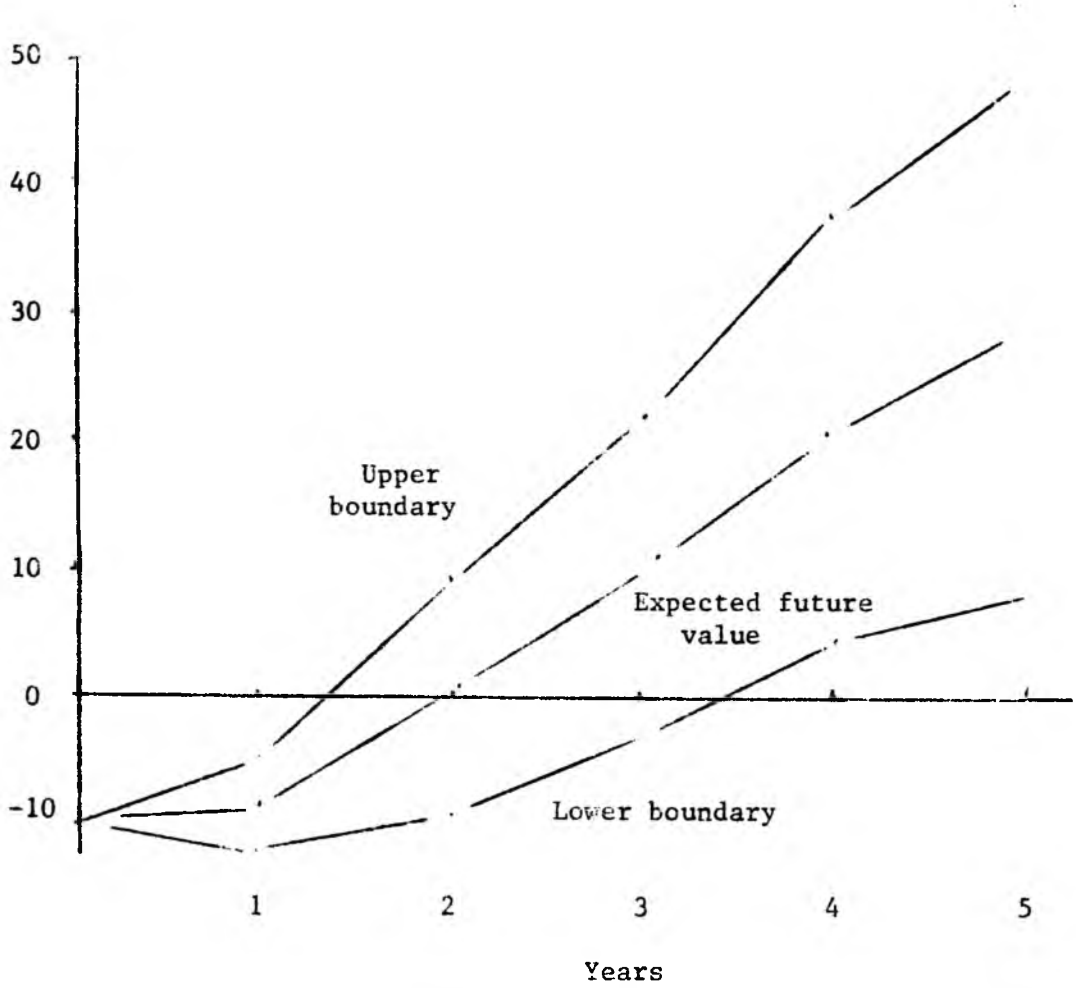
References

1. See Hertz, D.B. "Risk Analysis in Capital Investment." (1964)
2. Alternative terms are the discounted present value (Teichroew et al, 1965), net present value (Merrett and Sykes 1966), and present worth (Grant, and Ireson 1960).
3. See Markowitz (1959) for a simple explanation of the logic of this equation.
4. See C.C. Li, Population Genetics. (Chap. 12 "Theory of Path Coefficients"), Univ. Chicago Press 1955.
5. Cohen, K.J., and Elton, E.J. Inter-temporal portfolio analysis based on simulation of joint returns. Management Science, 14, p.5-18, 1967.
6. Grant, E.L. and Ireson, W.G. Principles of Engineering Economy. Ronald Press, 1960.
7. Hertz, D.B. Risk Analysis in Capital Investment. Harvard Business Review, p.95, Jan-Feb. 1964.
8. Markowitz, H.M. Portfolio Selection. Wiley, 1959.
9. Merrett A.J. and Sykes, A. Capital Budgeting and Company Finance. Longmans, 1963.
10. Murphy, M.C. A Stochastic Approach to Investment Appraisal. The Farm Economist , 11(7), p.304, 1968.
11. Pessemier, E.A. New Product Decisions: An Analytical Approach. McGraw-Hill, 1966.
12. Teichroew, D., Robichek, A.A., and Montalband, M. An Analysis of Criteria for Investment and Financing Decisions Under Certainty. Management Science, 12, 151, 1965.

EDITOR'S NOTE: Tables giving values of the various factors presented with the paper, have not been printed here.

DIAGRAM 4.

The Expected future value of the Project with risk estimates added



COUNCIL NOTES

Notes from Council meetings held June 2, July 17, September 14, 1970

EDUCATION COMMITTEE

An Education committee was set up, with John Jordan being co-opted to Council to act as its Chairman. A particular task envisaged for the committee was to make contact with the Training sub-committee of the N.D.C.'s committee on Productivity.

CONFERENCE

The Council agreed that the July conference was a success. The Programme Committee agreed to write a report with recommendations concerning next year's conference.

OVERSEAS VISITORS

The Council has had a possible visit by Dr Walsh, ex-president of ORSA, under consideration for some time. Dr Richard Bellman (of Dynamic Programming fame) is a potential visitor to New Zealand, in particular for the Mathematics Colloquium to be held next May. In both cases financial assistance is sought from the Society. There was a general preference to have Dr Bellman, all other things being equal.

NEW MEMBERS

Dr Ronald R. Allan

210 Manukau Road, Epsom, Auckland 3, works for Beca, Carter, Hollings and Ferrer, Consulting Engineers, Box 6345, Auckland, as a Consultant Traffic Engineer. His function includes analysis of traffic and transport operations, and transportation planning.

O.R. publications are:-

'A New Test for Server Lines' New Zealand Engineering Vol. 22 pp 257-67 (1965)
'Extension of the Binomial Model of Traffic Flow to the Continuous Case' Proc. Aust. Road Res. Bd. Vol. 3 pp 275-316 (1966)
'Special Methods in Probability Theory for Traffic Engineers' Proc. Aust. Road. Res. Bd. Vol. 3 pp 317-333 (1966)
'A Model for Correlated Traffic' Transportation Research Vol. 2 pp 235-248 (1968)
'On the Highway Crossing Problem' Proc. Aust. Road Res. Bd. Vol. 4, pp 529-548 (1968)
'Queuing on the Minor Road' Proc. Aust. Road Res. Bd. Vol. 4 pp 549-566 (1968)

Christopher G. Beath

127 Geraldine Street, Christchurch, is an assistant engineer with NZ Electricity Dept, and doing post graduate research at the University of Canterbury on dynamic optimisation of control of a thermal power station.

John F. Boshier

24 Brona Cres., Paremata, Wellington, is an assistant engineer with the N.Z. Electricity Department.

Peter M. Cashin

Electrical Engineering Dept., University of Canterbury, Private Bag, Christchurch, is doing a topic for Ph. D. Thesis work of 'Applications of hybrid computing to a learning system'.

A publication is:-

'Min cost path finding with incomplete cost information' 3rd Hawaii Conference on System Science.

Graham E. Coombes

C/o Electrical Engineering Dept., University of Canterbury, is doing research on the topic 'Energy Optimisation at Tasman' under a Tasman Pulp & Paper Co. Ltd, bursary.

Publications:-

'A Systematic Approach to an Industrial Optimisation Problem'
'A Sensitivity Analysis of Optimal Dynamic Trajectories' (Both presented at the 3rd Hawaii International Conference on Systems Sciences)
'Dynostat - A Parallel Optimisation Technique' to be published in IEEE Systems Science and Cybemeties

Graeme A. Cox

17A Hackthorne Road, Christchurch, is a Ph. D student in the Electrical Engineering Dept, University of Canterbury.

Rob M. Cresswell

P.O. Box 9177, Wellington, is Senior Engineer with the Post Office and is a member of the development group planning for the introduction of a new type of switching system into the N.Z. telephone network.

Ronald S. Ducat

19 Chaffey Crescent, Titahi Bay, is an Engineer with the Post Office, planning and supervising telecommunications installations.

David G. Elms

Department of Civil Engineering, University of Canterbury, Private Bag, Christchurch, Senior Lecturer. He did a study of the decision processes of building design for MOW to provide a computer based design system in 1969/70.

D. James Green

72 Edinburgh Street, Christchurch 2, is with the Electrical Engineering Department, University of Canterbury; is studying optimal control of Series Hydro-Electric Stations for an M.E. thesis.

Paul C. Gini

50 Parkvale Road, Wellington 5; OR Student.

David M.M. Hall

114 Newlands Road, Wellington 4; works for I.B.M. as Systems Engineer, in the development and installation of computer systems. He has been involved in development of oil company island distribution models, refinery linear programming models and econometric modelling programmes.

Michael R. Mayson

40 Staudy Street, Christchurch 4; N.Z.E.D. Fellow is doing a Ph.D thesis concerned with man/machine interaction, especially in the field of power system operation.

Howard B. Moore

14 Cargill Street, Tokoroa, is an Operations Research Analyst at N.Z. Forest Products, Kinleith. He has carried out or assisted in simulations of wood storage, paper mills, light vehicle utilisation, a saw mill using Fortran or Hocus.

M. Ross Palmer

24A Horokiwi Road, Newlands, is Chief Traffic Engineer with the Ministry of Transport.

Rob Podmore

Flat 1, 87 Rugby Street, Christchurch 1, is a Ph.D student in Electrical Engineering at Ilam University, engaged in analysis of power system transient behaviour.

A. Bruce Robson

3A Kiltie Street, Christchurch 4, is a Ph.D student in the Department of Electrical Engineering, Canterbury University. His topic is Pattern Recognition with Application to Problems in Acoustics. He has also been involved in Optimisation of Yacht Sail design, man/machine interface for collation and collection of medical records.

Brian F. Ross-Murphy

8 Titoki Street, Lower Hutt, is Organisation and Systems officer with Unilever N.Z. Limited. He has assisted in OR application, Organisation and Methods and Work Study and has been involved in application of Linear Programming to harvesting green beans, and in stock allocation methods.

J. Phil Scott

4 Stratford Way, Wilton, Wellington, is with Data Bank Systems Ltd, as Systems Analyst; is concerned with Education of Analysts, programmers and operators and will be investigating linear programming and stock control packages.

John A. Skurr

33 Simla Crescent, Wellington 4, is a Supervising Engineer with the Post Office and does Telephone engineering.

Malcolm J. Turnbull

8A Kipay Place, Christchurch 1, Ph.D student in electrical engineering concerned with forecasting electric power demand.

Chris J. Wallace

12 Crosby Terrace, Wellington, is studying for B.Sc (Hons) in Information Science.

D. Ritchie Wood

34 Bancroft Terrace, Newlands, is with Roading Div., MOW Head Office as Assistant Civil Engineer to assist the Economic Planning Unit.

Martyn F. Wright

22 Chartwell Drive, Wellington 4, is with N.Z. Breweries Hotels Division as Methods Engineer; concerned with Project control and reduction in operating costs.

LIST OF MEMBERS

OPERATIONAL RESEARCH SOCIETY

SEPTEMBER, 1970.

NAME	EMPLOYER	DISTRICT
R.R. Allan	Consultant	Auckland
R.L. Allen		Overseas
A.M. Ameye		Auckland
A.M. Anderson	Consultant	Dunedin
J.R. Anderson	B.P.	Wellington
B. Atkinson	Philips	Wellington
P. Bakala	Shell	Wellington
H. Barr(Dr)	Applied Mathematics Div.	Wellington
I.P. Bieleski	I.B.M.	Wellington
G.J. Bowler	B.P.	Wellington
A.D. Brownlie (Prof)	University of Canterbury	Christchurch
H. Bulder	Ministry of Works	Wellington
B.K. Campbell	Applied Mathematics Div.	Wellington
B.S. Campbell	B.P.	Wellington
A.H. Carr	Health Dept.	Wellington
P.M. Cashin		Christchurch
E.A. Christiansen	Philips	Wellington
R.A. Clements		Christchurch
J.C. Cocker		Overseas
D.C. Cook	Electricity Dept.	Wellington
J.P.M. Cornwall	State Advances	Wellington
E.A. Cottingham	Railways	Wellington
F.A. Coulter	N.Z. Forest Products	Tokoroa
G.A. Cox		Christchurch
R.M. Cresswell	Post Office	Wellington
J.H. Darwin (Dr)	Applied Mathematics Div.	Wellington
V.T. Davis	Whakatane Board Mills	Ohope
I.D. Dick	Mines Dept.	Wellington
P.J. Dohrn		Overseas
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D.G. Elms	University of Canterbury	Christchurch
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L. Evans	Victoria University	Wellington
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P.K. Foster (Dr)	PACRA	Wellington
J.F. Gabites (Dr)	Meteorological Office	Wellington
P.C. Gini		Wellington
C.A. Gollop	Auckland Regional Authority	Auckland
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R. Hadfield	I.B.M.	Wellington
D.M.M. Hall	I.B.M.	Wellington
K.R. Hall	Physics & Engineering Lab.	Wellington

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R.L. Hoole	Elastic Webbing	Wellington
J.J. Hunter (Dr)	University of Auckland	Auckland
P. Hyman (Miss)	Victoria University	Wellington
L.F. Jackson (Prof)	Victoria University	Wellington
E.G. Jacoby (Dr)		Wellington
M.B.C. Jameson (Dr)	N.Z. Refining Co.	Wellington
C.F. Jamieson	Shell	Wellington
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C.D. Johanson	N.Z. Forest Products	Kinleith
J.A. Jordan	I.C.L.	Wellington
G.H. Jowett (Prof)	University of Otago	Dunedin
B.Kaiser	Consultant	Wellington
L.F. Kenna	Building Research	Wellington
A.R. Kirkham	N.A.C.	Wellington
C.J. Kirkham	Unilever	Wellington
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T.A. Lusk	Electricity Dept.	Christchurch
A.T.G. McArthur	Lincoln College	Christchurch
A. MacCormick	University of Auckland	Auckland
R.D. MacDonald (WingCdr)		Wellington
M.S. McInman		
D.F. MacKenzie	Justice Dept.	Wellington
A.I. McKerchar	University of Canterbury	Christchurch
B. McWilliams (Major)	Defence	Wellington
N.G. Major	Ministry of Works	Wellington
T.W. Marks	University of Canterbury	Christchurch
M.R. Mayson	Electricity Dept.	Christchurch
M.M. Metwally (Dr)	Victoria University	Wellington
A.H. Milkop	State Services Commission	Wellington
J.H.G. Milne	Shell	
H.B. Moore	N.Z. Forest Products	Tokoroa
B.J. Noyce	Dalgety NZ Loan	Wellington
L.E. O'Brien	Unilever	Wellington
D.J. O'Dea	Statistics Dept.	Wellington
H. Offenberger	Polytechnic	Wellington
D.P. Page	Computer Bureau	Christchurch
M.R. Palmer	Ministry of Transport	Wellington
L.M.R. Paver	I.B.M.	Wellington
M.D. Purdie		Auckland
K.A. Reay	N.Z. Forest Products	Tokoroa
H.S. Roberts	Applied Mathematics Div.	Wellington
N.F. Roberts	Wool Research	Wellington
W.M. Robertson	Lane Walker Rudkin	Christchurch
A.B. Robson		Christchurch
B.F. Ross-Murphy	Unilever	Wellington
W.R. Schroder (Dr)	Massey University	Palmerston North
J.L. Scott	N.A.C.	Wellington
J.P. Scott	Databank	Wellington
K.E. Seal	Amalgamated Brick & Pipe	Auckland

List of Members Contd.

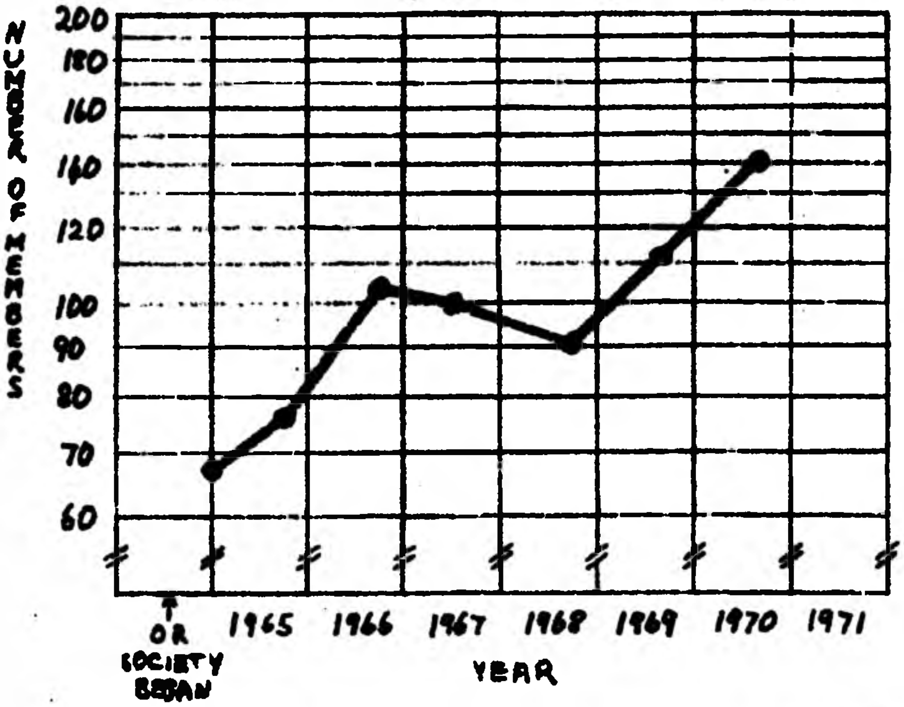
NAME	EMPLOYER	DISTRICT
R.S. Shirley	Ellis and Burnand	Hamilton
J.C. Silvester	Wellington Hospital	Wellington
P.V. Sim	Railways	Wellington
D.M. Simons	Tasman Pulp & Paper	Kawerau
R.J. Simpson	N.Z. Forest Products	Kinleith
J.A. Skurr	Post Office	Wellington
S. Slater	Victoria University	Wellington
W. Spencer	Grace Bros.	Wellington
G.T. Stallknecht III		Wellington
D.G. Stevens	Building Research	Wellington
C.A. Struthers		Wellington
M.J. Tarrant	Post Office	Wellington
G. Tate (Prof)	Massey University	Palmerston North
J.B.C. Taylor	University of Canterbury	Christchurch
V.J. Thomas	Applied Mathematics Division	Palmerston North
H.R. Thompson (Dr)	Applied Mathematics Div.	Wellington
R.F. Thrush (Sqn Ldr)	Defence	Wellington
M.D. Turner	Electricity Dept.	Christchurch
A.J. Van Zijl	Institute of Economic Research	Wellington
G.A. Vignaux (Prof)	Victoria University	Wellington
C.W. Walker	Shell	Wellington
A.R. Wallace	Applied Mathematics Div.	Christchurch
C.J. Wallace		Wellington
R.C. Wheeler	State Services Commission	Wellington
G. White	Computer Bureau	Christchurch
D.R. Wood	Ministry of Works	Wellington
R.M. Williams (Dr)	University of Otago	Dunedin
W.R. Williams (Cdr)	Defence	Wellington
T. Winiata	Dairy Board	Wellington
M.F. Wright	N.Z. Breweries	Wellington
V.A.W. Youl		Auckland.

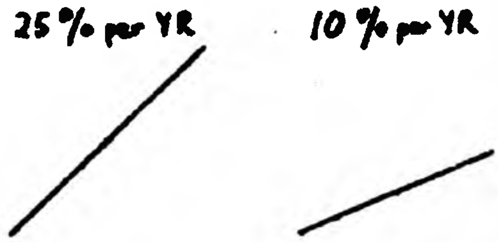
It is quite likely that there are errors in this list, because the Society is not in possession of up-to-date information. So if any part of it is out-of-date, either now or in the future, please let the Secretary know, at P.O. Box 904. Wellington, so that records and the addressograph plates can be corrected.

THE SOCIETY'S GROWTH

On the next page will be found graphs representing the Society's growth. As will be seen, the growth rate over the last two years has been a considerable 25% per year. Whether members can reasonably expect the continuation of this rate is an interesting question. The numbers of practising O.R. analysts, new analysts being produced each year and managers responsible for actual O.R. functions are known to be small. Future high growth rates would imply the recruitment of people with perhaps rather shallow general interest in O.R. Other organisations such as the N.Z.I.M. already exist for people with more general interests. Is it desirable that our Society become virtually a parallel society to these, duplicating their roles?

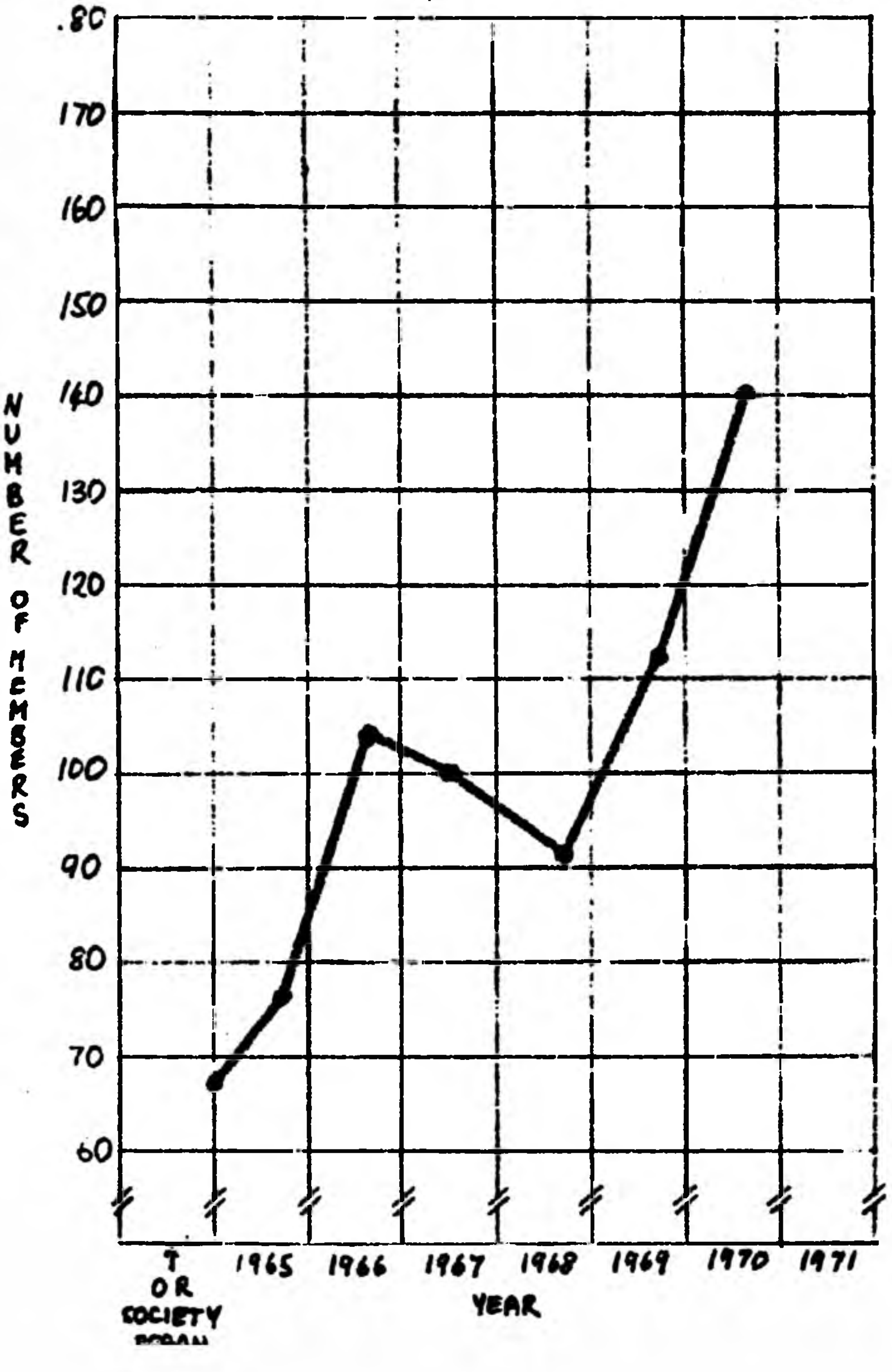
SIZE OF ORSOC, LOG SCALE v TIME

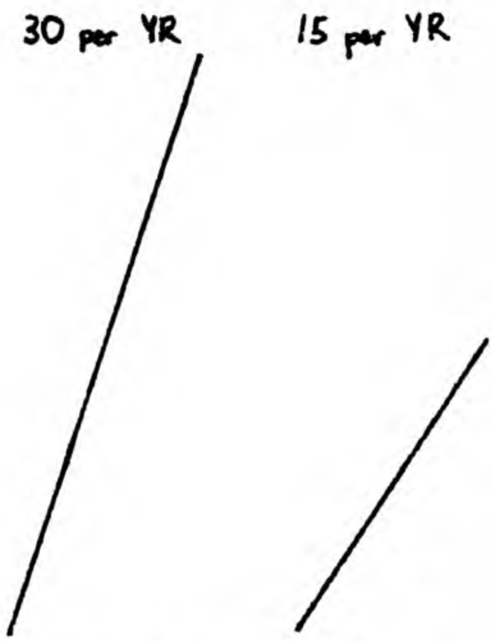




GRADIENTS REPRESENTING ANNUAL RATES OF INCREASE

SIZE OF ORSOC, LINEAR SCALE v TIME





GRADIENTS REPRESENTING ANNUAL INCREASES

NOTES FROM THE INTERNATIONAL AFFAIRS COMMITTEE

FIRST INTERNATIONAL DISCUSSION CONFERENCE ON O.R.

This conference will be held in Oxford in August 1971. It is being sponsored jointly by the three Universities of Lancaster, Pennsylvania and Sussex, and is recognised by IFORS.

The following is an extract from a letter from Prof. Patrick Rivett to Prof. Fraser Jackson.

> "Over the past couple of years I have been having discussions with Alec Lee, the President of IFORS, regarding an experiment with a new form of conference.
>
> We all of us say that the best things in a conference are the discussions and I have therefore, with the blessing of IFORS, arranged an international OR conference to be held at Oxford next year at which the whole emphasis will be on discussion alone. There will be no formal papers, no accounts of the discussion will be printed and we shall try to have an informal atmosphere with a limitation on numbers attending to about 150."

Brochures are available fron Prof. Fraser Jackson.

Discussion Leaders and Topics.

Professor R.L. Ackoff	The design of organisation and the systems that manage them.
Professor M.L. Balinski	Integer Programming: methods and applications.
Professor E.M. Beale	Development and application of mathematical programming systems for large computers.
Professor S. Beer	Societry systems.
Professor A. Blumstein	Law enforcement and criminal justice OR.
Professor A. Charnes and Professor W. Cooper	Operational Research and public affairs - especially urban affairs.
Professor C. West Churchman	Moral aspects of Operations Research.
Professor R.T. Eddison	The effective integration of OR into direction and management of the decision process.
Dr H.F. von Falkenhausen	OR models of the firm for strategic planning.
Dr G.J. Freney	Computer networks.
Professor Shiv Gupta	Manpower planning.
Dr D.B. Hertz	Concepts of operational risk in industry.
Professor F.S. Hillier	Towards an optimization theory for queuing systems.
Professor R.A. Howard	Decision analysis.
Professor A. Jensen	Scientists, civil servants and politicians - as elements in a decision process.
Dr J. Lesourne	Growth of the firm.
Professor A. Mercer	The modelling of behaviour in recurrent competitive situations.
Dr H. Muller-Merbach	Sequencing problems and their solution with heuristic methods and enumerative methods.
Professor A. Rapaport	Experimental games.

Professor P. Rivett	Corporate objectives - mythology or methodology?
Dr C. Salzmann	Corporate long term planning.
Professor M.G. Simpson	O.R. in university planning and management.
Professor R. Thrall	Future of journal publications in OR/MS and generally.
Professor K.D. Tocher	Control of systems.
Mr R.C. Tomlinson	The value of operational gaming. The role of OR in management and organisational studies.
Dr R.S. Weinberg	The application of management science techniques to the problems associated with the development of corporate policies and strategies.

There will be an opening (plenary) address to the Conference by Professor Patrick Rivett and a closing (plenary) address by Professor Russell Ackoff.

SEVENTH ANNUAL REPORT

for the year 1 October 1969 - 30 September 1970.

The year has been one of growth in numbers, costs services to members (we hope) and of contraction in our bank balance. The Council is concerned to improve services even more, especially to those members unable to attend the usual programme of meetings, and to develop the professional orientation of the society.

One of the first decisions Council made this year was to set up a series of committees to act in various areas of the Society's activities. These are in operation and much of this report is based upon their individual reports to Council. We have found that this system has worked well and would recommend to the next Council that the committee structure continue.

THE PRESENT POSITION

Membership

Once again the Society has grown in numbers, for the second successive year by about 25%. The present membership is comprised of 10 student, 101 Associate and 29 Full members, a total of 140.

The membership committee was comprised of Mr D. Cook (Chairman), Mr L.E O'Brien and Mr K. Hall.

Finance

We have reduced our balance considerably this year, as will be apparent from the Financial Statement. This was due to a deliberate policy of the Council to provide more services for members, particularly those out of access to normal Society meetings. It will be seen that much of the cost increase has been in Newsletter and in Conference costs. We have also been paying IFORS dues and Abstracts costs.

It is essential that costs be covered and to this end the Council will recommend to the AGM some increases in subscriptions.

WHAT THE SOCIETY IS DOING

International

With its election to IFORS, the Society has achieved international standing and corresponding obligations. All Full members of the Society are now receiving copies of the International Abstracts in Operations Research, published for IFORS.

International Committee, consisting of Prof. L.F. Jackson (Chairman), Dr P. König and Mr D.J. O'Dea, is now dealing with much of the correspondence from IFORS and will provide the abstracting service which is required of us as the N.Z. contribution.

Public Relations

The Committee consisted of Mr P. Bieleski (Chairman), Prof. L.F. Jackson, and Mr B. Kaiser.

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Education

This Committee was formed later in the year than the others, but under its dynamic chairman has started activities in the area of surveying O.R. Courses and determining the needs of O.R. Education in New Zealand.

The Committee was Mr J. Jordan (Chairman), Mr B. Kaiser, Mr B.R. Slocombe and Mr T. Naylor.

Meetings

The Programme Committee, consisting of Mr F.C. Wheeler (Chairman), Dr H. Barr, Mr C. Walker and Mr E. Christiansen, was responsible for arranging the programme of meetings and for the Annual Conference, once again held in conjunction with the N.Z. Statistical Association in Wellington.

On the recommendation of the Programme Committee, Council has pleasure in awarding the Lecture Prize for the best paper presented to the Society by an Associate or Student member, to M.J. Tarrant for his paper entitled "The Optimum Provision of Buried Telephone Cable", published in No. 3, Vol 5, of the Newsletter.

The following meetings were held during the past year:

1969	20	October	I.D. Dick G.A. Vignaux A.K. Milkop	"Operational Research in the Mining Industry".
	20	November	(Annual General Meeting) L.J. Harper	"Applications of Operational Research to Marketing".
1970	27	April	M.J. Tarrant	"The Optimum Provision of Buried Telephone Cable".
	15	June	M.W. Foster	"An Attempt to Optimise the Coastal Distribution of Oil Products".
	2	July	(Annual Conference) C.D. Johanson	'Minimising Paper Trim Loss by Computer".
			H.B. Moore	"The Hocus Simulation Language and Some Applications".
			A.T.G. McArthur	"Risk Estimates in Project Evaluation".
			J.J. Hunter	"Civil Defence Casualties Estimation"

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1970	20	July	(Combined meeting with Work Study Society)	"The Use of Statistics in Industrial Controls".
			H.R. Thompson K.E. Seal L.E. O'Brien P.Mahon	
	31	August	A. MacCormick	"The Economics of Manufactured Gas with an Uncertain Natural Gas Arrival Date".
	23	September	(Operational Research in Electricity Supply)	
			J.F. Boshier	"Economic Power System Voltage Control".
			G.E. Coombes	"Computer Control and Optimisation of Power System at Tasman".
			D.J. Green	"Optimal Use of Water Pesources to Meet a Daily Load Demand".

Publications

The Publications Committee, Mr B.K. Campbell (Chairman and Editor), Mr L.E. O'Brien, and Mr M.J. Tarrant, are responsible for the Newsletter, and other publications of the Society.

Four issues of the Newsletter, totalling 60 pages with a circulation of about 150 copies were prepared during the year. Plans are for more frequent issues during the 1970-71 year.

Council approved of a project to provide a combined DSIR-OR Society (single issue) Bulletin aimed at promoting the application of O.R. in New Zealand and the committee is co-ordinating this. The Committee investigated the possibility of producing a Journal for the Society, but Council, while recognising the long-term desirability of this aim, felt that this should be delayed because of the costs involved.

Council

The Council met 8 times during the year.

President:	Prof. G.A. Vignaux	7 att. 1 ap.
Vice-President	Prof. L.F. Jackson	4 att.
Hon. Secretary	A.H. Milkop	8 att.
Hon. Treasurer	A.R. Wallace	4 att./4 possible att.
	C.W. Walker	4 att. 1 ap./5 possible att.
Hon. Auditor	P.D. Hasselberg	
Council	H. Barr	7 att. 1 ap.
	I.P. Bieleski	1 att.
	B.K. Campbell	7 att.
	D.C. Cook	3 att. 2 ap.
	B. Kaiser	4 att. 2 ap.
	D.J. O'Dea	5 att. 2 ap.
	R.C. Wheeler	7 att.
	J.A. Jordan	1 att. 1 ap./2 possible att.

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