JOHANNESBURG OR GROUP

News and Views

April 1969

(Your news and views will be welcomed and published)

Next Meeting

Chairman: Mr. G. van der Veer

Speaker: Mr. Bob Tandy

Subject: "Management Games"

Date: April 16th

Time: 8 p.m. - 9.30 p.m.

Venue: Room SS4 (Social Sciences Building)

To get to the Social Sciences building, enter the University at the main gates on Jan Smuts Avenue. Go round the circle and north, down the hill. The building is a big new yellow block on the left of this road. To get to SS4 enter at the West entrance and go up the main stairs to the second floor. SS4 is directly opposite the stairs.

Agenda:

1. Chairman's Welcome
2. "Management Games"
3. Questions
4. Matters of Special Interest
5. Tea and Talk

Next Meeting + 1

Chairman: Mr. Joslin

Panel: Mr. Hammarström
Mr. Joffe
+ another member

Subject: A real problem, currently being tackled by the South African Railways, will be presented to a panel of three, who will attempt to find a solution in front of the meeting.

The procedure will be:

a. A description of the problem will be circulated to all members of the OR group before the meeting (including the panel).

b. The members of the panel will not be allowed to discuss the problem with each other, but will be encouraged to ask questions of the S.A.R. (Mr. van der Veer).

c. At the interactive meeting a chairman will preside, while the panel put their views to each other and to the meeting, and attempt to arrive at a solution.

Date: May 14th

Time: 8 p.m.

Last Meeting

We were treated to a clear and illuminating talk by Mr. Hattingh on some studies undertaken by him and Professor Venter at SASOL. Their problem was to find the income for the Arge Synthesis plant as a function of the operating variables. To do this they had to find the proportions in which the incoming gases combined in the reactor to produce the resultant gases. These constants were found by a regression technique and it was interesting to see that instead of minimizing the sum of squares of residuals by the usual method, quadratic programming was used to find the best fit. This was done so as to constrain the answers to be positive because no incoming gas can make a negative contribution to a resultant gas.

Dr. Sichel made the comment that the high multiple correlation coefficient of 0.8 obtained for the final model may have been due to the number of observations being only slightly more than twice the number of terms in the model. Mr. Hattingh replied that studies of surfaces through the model had shown that it was a good description of the Arge plant.

SIG Activities

The purpose of the Special Interest Groups is to help people to work together in depth, independently of our monthly meetings, on their special interests or problems. If you are interested in any of the activities outlined below, please contact the SIG leader. If you would like to lead a group in an activity not yet catered for, please inform any member of the committee.

Cybernetics: Mr. Mike Roberts 838-3581

Dynamic Programming:	Mr. Tom Rozwadowski	48-1028
Econometric Models:	Mr. John Joslin	28-1500
Forecasting:	Dr. John Ryder	838-3581

The next meeting of this SIG will be at 4 Stevens Road, Blairgowrie, Randburg, from 5.30 p.m. to 7.30 p.m. on 23rd April, 1969. There will be a discussion on the effect of lead time fluctuations on stock systems.

All are welcome.

Simulation:	Mr. Gert van der Veer	713-4201

The next talk will be given by Mr. Jack Curtis, entitled "South Africa vs MCC", on April 14th.

Statistical Quality Control:	Dr. Sichel	724-8172
OR in the Construction Industry:	Mr. V. Shaw	74-6011

A Mathematical Programming Solution to the African Wire Ropes Production Planning Problem

R.T. Rozwadowski

Synopsis

A mathematical formulation is presented for the problem of determining how should the raw wire stocks be processed to obtain with maximum probability a required patented wire stock mix.

The Problem:

The problem of controlling the patented guage wire stocks has many aspects. A solution to only one of these aspects is presented here. If it is assumed that it is possible to determine the quantities which it is desirable to keep in inventory of each of intermediate products (patented wire of a specific guage and tensile by an inventory control model, then the problem remains of determining the quantities of raw wire of a specific nominal carbon content which have to be drawn to a specific patented wire guage. For this latter problem a mathematical programming model is formulated. The solution of this model will yield the optimum initial production pattern. In the sense of this exercise by 'optimum solution' is understood a production allocation which will maximise the probability of producing the required inventory quantities.

The Mathematical Model:

The following variables are defined:

(i) x_{jk} = quantity of raw material (standard guage coil) of nominal tensile k which has to be drawn to guage j.

(it is assumed that the relation between nominal tensile and initial carbon content is known)

The value j ranges from 6 to 18 in increments of 1

The values of k are as follows:

49, 52, 56, 58, 63, 67, 70, 74, 77

(these correspond to available initial carbon content.)

There are thus 117 variables of the x_{jk} type.

(in actual case there may be less of these variables as some may not be practical for actual production - these can be excluded from the model.)

(ii) The outcome of the initial production allocation is uncertain because the nominal tensile strength are known with poor precision. However in quite a large number of cases it is possible by means of the diagonal rule to regard a patented guage wire of guage j' and tensile i' as equivalent to guage j and tensile i.

For example patented wire of tensile 50 by 92% reduction will produce the same final product as patented wire of tensile 67 by an 85% reduction.

We define:

$e_{ji,j'i'}$ = Quantity of patented wire of guage j' and actual tensile i' which can be regarded by virtue of the diagonal rule as equivalent to patented wire of guage j and actual tensile i.

The number of the variables in the model is equal to the total number of possibilities of the application of the diagonal rule.

The diagonal rule only applies if $j \neq j'$ and $i \neq i'$.

However in the above definition we can also include the case where $j = j'$ as it is possible by processes such as increasing the speed of drawing, reducing water cooling and reduction of the number of dies to increase the final tensile and hence to equivalence patented wire of the same guage but different tensile.

While the above variables appear in the model and would be determined numerically when the model is solved they only represent probable values with the actual values being determined by a subsequent application of the diagonal rule on patented wire stock, when patented wire is used in the second phase of production.

The following constants are defined:

(i) P_{ik} = probability that raw wire with a nominal tensile k has actual tensile i.

(i = 41, 44, 47, 50, 53, 56, 59, 62. 65, 67, 70, 73 i.e. admissable values for actual tensile).

(ii) d_{ij} = quantity required of patented wire of tensile i and guage j.

Development of the Contraints

(i) Production to meet requirements:

We have that $\sum_{k} P_{ik}\,x_{jk}$ is the probable quantity which will be produced of patented guage wire of tensile i and guage j.

We also have that the total probable contribution from the diagonal rule to patented guage wire of tensile i and guage j is equal to $\sum_{j',i'} e_{ji,\,j'i'}$

Since some of the product of tensile i and guage j may be used as equivalent to wire of other guages and other tensile strength we may have to reduce the amount of this product which is initially produced by

$$\sum_{i,i} e_{j'i',\,ii}$$

Hence the production contraint to meet the requirements is as follows:

Probable Initial Production

plus gain from diagonal rule
Less loss from diagonal rule
is equal to production requirements

$$\text{i.e.}\quad \sum_{k} P_{ik}x_{jk} + \sum_{j',i'} e_{ji,\,j'i'} - \sum_{j,i} e_{j'i',\,ji} = d_{ij} \quad \ldots(1)$$

for all i and j (156 constraints)

Other forms of this basic constraint could be used. Two examples are as follows:

a. If it is assumed that the application of the diagonal rule will result in some losses (say 50%) we could write (1) as

$$\sum_{k} P_{ik}x_{jk} + \sum_{j,i} {}^{`}95\; ji,j'i' - \sum_{j,i} e_{j'i',\,ji} = dij \quad \ldots (1a)$$

b. If we wish to allow for over and under production in an explicit way we can define the variables:

Y_{ij} = quantity by which demand dij is unsatisfied

Z_{ij} = quantity by which demand dij is over satisfied.

We would then have:

$$\sum_{k} P_{ik}x_{jk} + \sum_{j',i'} e_{ji,\,j'i'} - \sum_{j,i} e_{j'i',\,ji} + Y_{ij} - Z_{ij} = dij \;\ldots (1b)$$

appropriate values would have to be introduced in the objective function corresponding to the variables y_{ij} and z_{ij} to penalize over and under production.

(ii) Repetive Application of the Diagonal Rule

The above constraint (1) would be sufficient for the model provided that the diagonal rule in the solution is not applied repetively (this could make all products equivalent). The repetive application of the diagonal rule can be prevented:

a. by introducing the constraint that only the initial production can be equivalenced by the application of the diagonal rule i.e.

$$\sum P_{ik}x_{ik} - \sum_{j,i} e_{j'i',\,ji} \geqslant 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

for all i and j

Constraints (2) could double the total number of constraints.

b. A selection of the diagonal rules on basis of those which would actually tend to be used can also be used to prevent the repetive application of the diagonal rule.

c. Similarly degradation factors such as a 5% loss or high penalties for the use of the diagonal rule variables in the objective functions can be used to prevent the appearance of repetive diagonal rules in the solution.

(iii) Shortage of Raw Wire

A model comprising equations (1) and (2) assumes that there is unlimited availability of the raw material. If this is not the case we can define a constant

a_k = quantity of raw wire of nominal tensile k which is available.

we then have

$$\sum_{j} x_{jk} \leqslant a_k \quad \text{for all } k \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

as a possible constraint on raw wire in short supply.

(iv) Other Constraints

Other constraints can be freely introduced to prevent certain real production constraints being violated or undesirable production patterns from appearing in the solution.

(v) Positive Variables

All variables in the model are assumed to be greater or equal to zero.

Objective Function

The constraints (1) to (3) are not sufficient to determine unique values of the variables. A set of unique values can be obtained when a function of the variables in the model is maximised or minimised. In our case we wish to ensure that the probability of obtaining the required patented guage wire stock is maximised. This can be achieved if the solutior produces as few initial choices of the variables x_{jk} as possible and that selected x_{jk} quantities all be reasonably large. This will be achieved if a function of x_{jk} squared is maximised. That is a function of the form

$$\sum_{jk} c_{jk} \; x_{jk}^2 \quad \text{where } c_{jk} \text{ are some constants}$$

(possibly equal to 1)

To discourage the use of the diagonal rule a further term can be introduced giving a function to be maximised as follows:

$$\sum_{jk} c_{jk} \; x_{jk}^2 \; - \sum_{j,i,j',i'} c'_{ji,j'i'} \; e_{ji,j'i'} \; \ldots\ldots\ldots (4)$$

where $c'_{ji,j'i'}$ are appropriate constants which have to be determined by trial and error.

Method of Solution

The above problem is a quadratic linear programming model with a set of constraints where the linear programming decomposition algorithm can be useful in reducing the size of the problem. The size of the problem is however not too great for a standard quadratic programming computer code and a medium sized computer.

Physical Constants

The probability factors P_{ik} have to be determined numerically (these can be updated as new values become available from week to week) as well as the set of possible diagonal rules. The model further assumes that the desirable inventory levels of each patented guage wire stock is known.

Use of the Model

Besides being suitable for determining the initial production on a weekly or bi-monthly basis the model can be used in reverse i.e. to determine the optimum quantities of the raw wire stocks.

Solution of the model besides producing the optimum production schedules will also produce financial information which can be used for effective product pricing. These values known as shadow product art or opportunity costs are often more valuable to management than the actual production schedule.

Furthermore the model enables simulations to be run very economically in investigations covering new products or processes.

Interpretation of the Results

The model has to produce a 'reasonable' or acceptable solution. To do so it has to be debugged i.e. the results must be carefully scrutinised before the model is put into routine use (Perhaps some constraints have been overlooked and these may have to be introduced). It can easily happen that certain production rules of thumb can be established from the initial results of the model thereby making the regular computer runs unnecessary.

The African Wire Ropes Problem - Dr. J.A. Ryder

1. Following on Mr. Cohen's figures, actual average production lead times exceed the physical time for manufacture by factors of 20 or more. It follows that the most important effect of setting up intermediate wire stocks will not be the chopping off of a mere couple of days in the production lead time, but in the provision of dependable stocks of wire of known properties, thus largely eliminating costly (very time consuming) re-cycling, re-manufacturing runs.

2. Stocks should be set up at the earliest stage possible, so that (a) the number of items controlled is as small as possible (lower admin. costs), (b) the volume within each item is as high as possible (easier forecasting, lesser problem of the 2-week shelf life).

3. The suggested point of stockholding is immediately after the initial roughing/patenting phase. Stocks of guage wire should be kept in 3-ton intervals for each guage.

4. Normal stock control theory is applicable, with the ROL's and EOQ's applicable after observing some 3-6 months of demand behaviour. Maximum levels should also be set up (as well as 'greater than 2 weeks' warning notices) so as to allow planners to utilize the diagonal rule to use up stock build-up in little-used classifications.

5. Final thoughts: Dr. Sichel's recommendation that carbon content be measured at the rod stage bears very careful following up, as there is little doubt that this is the best point for holding stocks:

   a. No. of items is minimal (only 1-3 guages, in 5 pt. carbon ranges)

   b. No shelf life problems.

   c. Rod cost less than guage wire costs, therefore stockholding costs reduced.

   d. Stocks already exist in the rod-yard, but presumably classified in 10 pt. rather than in 5 pt. ranges.

OR in Agriculture

We have received a letter from Mr. M.J. Stewart who is one of the Natal members of the OR Group. He writes:

"My interests lie in industrial sugar cane agriculture and I am in the process of initiating a research project using OR methodology. But agriculture in general is very traditional and I am not aware of anyone who has had the opportunity of applying OR to agricultural problems.

Should you know of any interested persons or organisations, either in South Africa or overseas, please drop me a line and should you come across a case history on any agricultural OR subject, I should appreciate the reference."

If you have or know anyone who has similar interests Mr. Stewart will be pleased to hear from you. His address is:

Darnall Mill,
P.O. Darnall,
NATAL.

National Co-ordinating Committee

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Mr. Joslin	28-1500
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