AN OPERATIONS RESEARCH APPLICATION IN THE FOOD INDUSTRY

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INTRODUCTION

This paper is a description of how a computer is used both as a management decision tool and as a high-speed calculator which takes the tedium out of industrial nutrition. We will attempt to show how the concept of computer - controlled feed formulation was successfully utilised at a time when grain availability was at its lowest point for some years, enabling NRM Group to hold its feed prices throughout this period.

Definition of the problem

NRM Group operate eleven mills throughout New Zealand producing a range of animal feeds. The bulk of these feeds are produced for chickens and pigs, but feeds for other poultry, for horses and trout are also produced. Regardless of the recipient of the feed, the problems confronting the nutritionist are similar and consist of the following.

a. A minimum level of nutrition must be maintained. Each ingredient is analysed for its nutritional constituent levels. (See Appendix A for the list of constituents that are considered). The nutritionist must select a series of ingredients which, when mixed together give levels of constituents as required by the particular animal. It must be remembered that both upper and lower limits on most constituents are considered, and that there is a choice of about twenty-five ingredients for any one feed, so that the production of a feed conforming to the nutritional specification is in itself a mammoth task.

b. A close watch on the cost of feed must be maintained. The animal feed industry is under price control and so it is desirable to obtain the ingredients of a feed at the lowest possible price to keep the cost of the feed at a minimum.

Inclusion of some of the ingredients available is mandatory to maintain the desired nutritional levels and so the problem is to estimate when to buy the ingredients to take advantage of

i. the lowest cost price

ii. the requirements of the mill for each ingredient.

c. Mills like the one at Auckland run continuously at an output of about 20 tons per hour. If an ingredient supply embarrassment arises, a reformulation must be executed in the minimum of time. There sometimes occurs the situation where the quantity of a particular ingredient available is insufficient for the demand imposed on it and a selection of more expensive

ingredients must be substituted in the feed. It is almost impossible for the nutritionist to reformulate all of the feeds being produced, reassess the ingredient situation and allow enough time for the mill to change over to the new formulation before the supply of the scarce ingredient is completely exhausted.

d. The maximum allowable levels of any ingredient in a feed must be adhered to. There exists for most ingredients a maximum level of content which must not be exceeded.

For example, maize is an ingredient which is rich in most of the constituents needed in a feed, but if the feed is to be given to a broiler chicken, then the maize content must be limited or the flesh of the chicken will become tainted with a yellowish tinge. Similarly, a feed must not contain too much salt or the feed will become unpalatable to the animal.

The need for a computer application.

We see that the nutritionist has a mammoth task confronting him. He must :

i. Formulate feeds to have specified nutritional levels from a vast number of ingredients.

ii. Be prepared to reformulate any feed if an unexpected condition arises.

iii. Decide on the maximum prices which can be paid for ingredients.

iv. Decide on the quantities of ingredients required by each mill.

v. Attempt to keep the cost of the feeds down to a minimum.

vi. Perform the above tasks in the shortest possible time.

A computer application based on an optimisation routine (such as simplex method) could be utilised to minimise the cost of the final feed. This routine would quickly give the ingredients needed for each feed, and of course, the minimum cost of the feed. It is important to note that the routine could be based on an analogue computer or on a digital computer.

The ideal computer routine would, therefore

i. Reduce the time taken on the tedious task of formulating a feed conforming to the specified nutritional and ingredient availability constraints.

ii. Optimise the cost of the feed as defined.

iii. Give an indication of the maximum prices of the ingredients, and the quantities of ingredients required.

iv. Give an indication of which of the ingredients of a feed are constraint - critical.

History of L C M application

The linear programming approach to feed formulation began outside General Foods Corporation. The nutritionists at Northern Roller Mills learnt of the model from both overseas travel and technical literature, which invariably involved the use of analogue machines. Their volume of work increased considerably as mills throughout the country were taken over by NRM, and combined with the wide fluctuations of ingredient availability and price, and overseas developments, this led to the initial specification of the need of a machine.

Experimentation was begun at General Foods Corporation on the 1902A, using two I C L Software packages, (3). Linear Programming MK 2 (XDL8) proved unsatisfactory for the user of the output, because the solution was described in mathematical detail, with very little descriptive assistance for interpretation. Least Cost Mix achieved a satisfactory solution and output, but in doing so tied up 4 tape decks (total available at that time) and took 20 minutes of processing time per formulation, quite unsatisfactory from an operating aspect.

I C L acknowledged the need of improvement and released a program listing of L C M.

Three of the tape files were then written to core and processing time reduced to five minutes per formulation, thus operationally successful. The program required both constant data and individual formulation constraints to be input on cards, generally numbering over 300. The constant data consisted of the Analysis Matrix (constituent levels in ingredients), Cost Rows (Cost of ingredients) and Exclusion Sets (geographic availability of ingredients). The formulation constraints set limits to both constituent level and ingredient usage for each feed. Chicken feeds at the Ford St., mill were taken as a pilot run, and reference to current formulation costs, proved the substantial cost savings in the Linear Programming method. Following minor format changes and insertion of new information in the output sheet, progressive implementation over the whole of N.Z. was commenced.

Shortcomings of L C M.

1. The processing time involves reading 300 cards, core size 24K and 5 minutes per formulation, and this is not satisfactory in a multi-programming environment.

2. Handling and Auditing information. Constant data is input every run, with the danger of loss and delay.

3. High turnround time from receipt of new information and posting of output, (A combination of 1 x 2), leads to dissatisfaction for user.

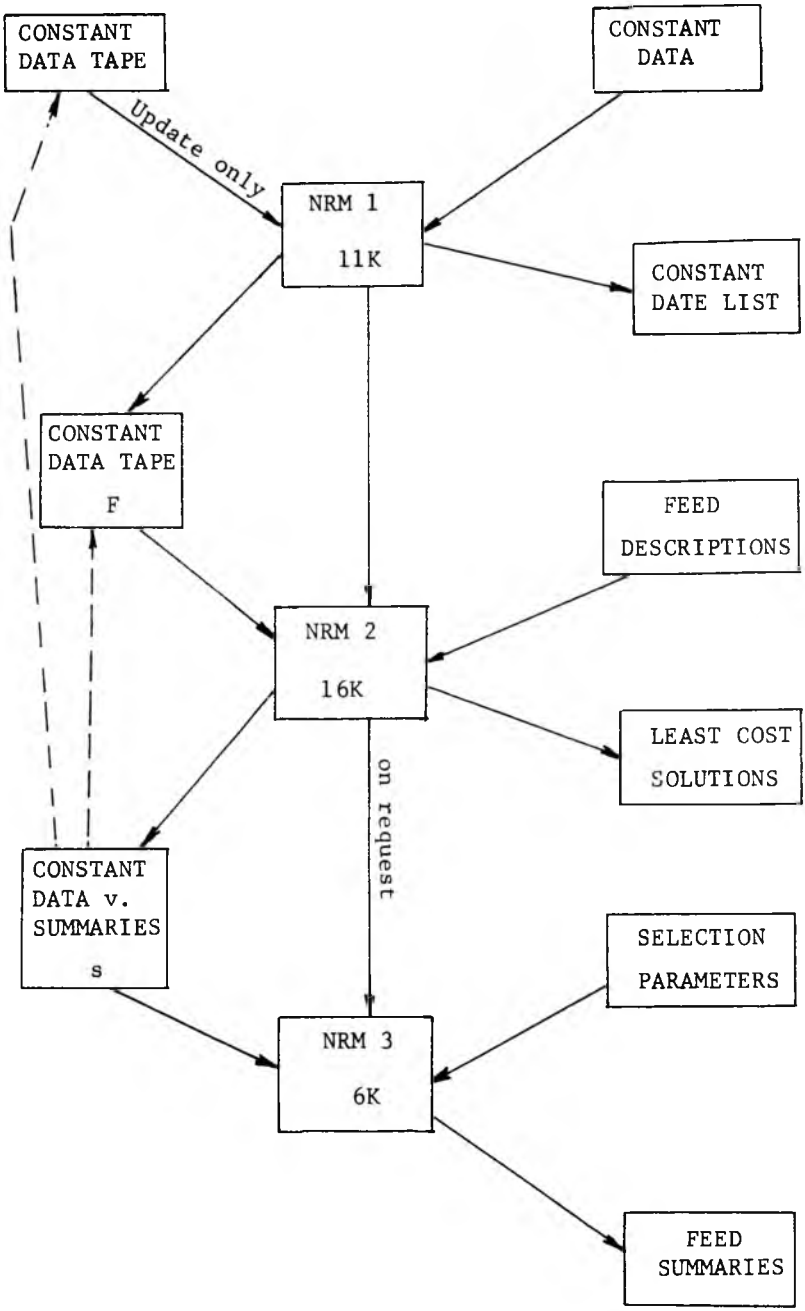
4. Not all mills could measure ingredients to the last pound. Many plants used bag lots eg. 50 lb, 112 lb, to which the least cost formula could not apply. (Subsequently a branch of the program was written to compute in bag and half - bag lots for ingredients used this way. Comparison with the least cost result for the identical feed has convinced mill managers to install continuous weighing devices).

5. Only part of the nutritionists workload was eased. He had no summary of current formulations and he still had to estimate ingredient usage and stock levels.

Description of the present system

The present system has evolved from the original Least Cost Mix package and incorporates various enhancements which were deemed desirable, both from the nutritionists' point of view, and from the D.P. aspect. It was found desirable to incorporate a file of feed description summaries into the Least Cost Mix package to enable the nutritionist to obtain summaries of feed descriptions on request. To reduce the volume of card data required by the package, all of the constant data was written to tape.

The present system consists of three programs, named NRM1, NRM2, and NRM3.


CONSTANT DATA TAPE
Update only
CONSTANT DATA
NRM 1
11K
CONSTANT DATE LIST
CONSTANT DATA TAPE F
FEED DESCRIPTIONS
NRM 2
16K
LEAST COST SOLUTIONS
on request
CONSTANT DATA v. SUMMARIES s
SELECTION PARAMETERS
NRM 3
6K
FEED SUMMARIES

The original Least Cost Mix package was split into two programs, called NRM1 and NRM2.

NRM1 maintains a tape file of the constant data needed by the second program. This constant data consists of the Analysis Matrix, the ingredient and constituent names and ingredient cost and availability data for each of the mills. The constant data is loaded onto tape from cards. All numeric data is converted to floating - point before it is written to tape.

NRM2 has two main functions. Its primary function is to perform a form of revised simplex optimisation on the feed constraints presented to it and produce the minimum cost feed formulations. The cost and availability data and the Analysis Matrix are obtained from the tape produced by NRM1 and the feed descriptions are read from cards. A detailed report is produced for each feed formulation produced.

The report consists of :

1. The cost solution in dollars per total weight of feed (e.g. one ton)

2. The individual costs and weights in the least cost solution of the ingredients in the solution.

3. A cost ranging for which each ingredient in the solution would remain in the solution in the same quantity.

4. The alternative ingredients (i.e. the ingredients which do not appear in the solution), their costs, and the minimum cost at which they would appear in the solution.

5. An analysis of the constituents contained in the final solution.

6. A list of active constraints. This is a list of the constraints which are critical in the final solution - and hence are the constraints which limit the cost of the solution. The list also contains information

on the effect of easing or tightening of these constraints.

7. A list of constraints used to define the feed.

This was the entire function of the original least Cost Mix package.

The second function of NRM2 is to maintain a summary file of all feed formulations. This file contains details of the optimal cost, the ingredient solution and the constituent analysis for each feed. The file is "piggy backed" on to the end of the constant data. The summary file was introduced into the system to facilitate the production of a feed summary report which enables the nutritionist to tie back the demand for ingredients to their availability. The file is used in the third stage, NRM3.

NRM3 produces a summary report of feeds formulated by NRM2. The report is used by the nutritionist to check on ingredient usage by mill, that the nutritional levels of each feed are indeed satisfactory, and that the optimal cost of each feed is also satisfactory.

The above changes were incorporated for three reasons :

a. NRM1 and NRM2 were written so that core usage would be reduced; thus enabling the multi-programming facility of the computer to be used to a greater extent. This tends to reduce turn-around time since delays caused by waiting for computer time were reduced.

b. Having the constant data on tape reduced the possibility of delays being caused by a large pack of cards being accidentally dropped. (It may be remembered that the original Least Cost Mix package required the constant data to be input from cards).

c. NRM3 produces in a matter of seconds a report which the nutritionist previously compiled by hand, spending up to three days collecting data and transposing figures from the feed formulation report.

The present system still gives rise to a large turn-around time because delays are caused in transmitting

data from NRM to the computer, and in posting the reports back to the nutritionist.

Future Enhancements

There will be two stages of incorporating future enhancements into the system.

Stage 1

Following the upgrading of the G.F.C. computer to a real time system the Least Cost Mix system will be converted to utilise real time facilities. The hardware for this will consist of a visual display unit connected via a real time link to the G.F.C. computer. The VDU will enable the nutritionist to have immediate access to the computer.

The three programs will be converted to use disc files instead of tape, and an editor program will be written to communicate with the VDU. The nutritionist will be able to interrogate a "constraints" file (containing all feed definitions) using the VDU and the editor program. After manipulating the feed definitions he wishes to use, he will be able to initiate the running of NRM2 to produce the Least Cost Mix solutions for these feeds. A summarised report will be displayed on the VDU and the full solution report will be written to disc, for each feed solution produced.

The nutritionist will be able to select the feeds for which he requires the full report, indicate this fact to the editor program which will produce the hard-copy report for posting to the nutritionist.

Stage 2

It is envisaged that a file of ingredient availabilities will be created for each mill. Ingredient usage will then be automatically referred back to this file and a warning will be produced whenever the ingredient demand is greater than the availability. This facility will allow the nutritionist to have exact control over the availability of ingredients.

At the present time, an investigation is being carried out to discover the feasibility of introducing the Least Cost concept into the production of ice cream and cakes, (4).

Summary.

To date, the Least Cost Mix system handles the products of two of the eleven mills. The two mills may be reviewed as pilot schemes for the remaining nine mills. The system has been running successfully for the past 12 months at these two mills, and has enabled the company to hold the selling price of the feeds. The drought last summer caused an acute shortage of ingredients, causing the cost of ingredients to soar. However by manipulating the Least Cost Mix package, NRM Group managed to minimise the increase in cost, enabling prices to be held.

The system has also enabled nutritional levels of the feeds to be more easily controlled - hence bringing about uniformity of content and higher levels of quality control.

The exercise described on bagged ingredients has proved that it is feasible to install continuous weighing equipment at all of the mills, doing away with the old technique of using only an integral number of bags of an ingredient.

Overall, the system has proved to be well worth while in that it has freed the nutritionist from the laborious task of feed formulation calculations, and has allowed him to devote more time to the important activities of animal nutrition.

References

1. Linear Programming Hadley

2. Operational Research Techniques White, Donaldson and Lawrie.

3. I C L user Guides (a) Least Cost Mix

(b) Linear Programming MK 2

4. I B M DP Application : LP - Ice Cream Blending

Acknowledgement for permission to publish this paper is made to the Management of General Foods Corporation (New Zealand) Limited., a division of the J. Wattie group of Companies.

APPENDIX A

List of constituents which are considered important to feed formulations :

1. Crude Protein
2. Productive Energy)
3. Metabolisable Energy) - Measure of Energy content
4. Oil (Fat)
5. Fibre (Bulk)
6. Lysine)
7. Methionine & Cystine) - Measure of aminoacid content
8. Calcium
9. Phosphorous (Inorganic)
10. Ash (Total inorganic content)
11. Choline (a vitamin)
12. Salt.

APPENDIX B

List of ingredients which are considered when producing feed formulations.

1. Wheat
2. Maize
3. Barley
4. Oats
5. Wheat Bran
6. Wheat Pollard
7. Screenings
8. Meat and Bone Meal
9. Liver Meal
10. Fish Meal
11. Blood Meal
12. Tallow
13. Molasses
14. Lucerne Meal
15. Linseed Meal
16. Pea Meal
17. Copra Meal
18. Grass Meal
19. Milk Powder
20. Limestone
21. Sugar
22. Bone Flour
23. Salt
24. Lysine
25. Methionine