Operations Research Applications to Nutrition and Production

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Introduction

"It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness…"

Charles Dickens, A Tale of Two Cities

We live in times of difficulty and uncertainty. Operations Research was born in another time of difficulty and uncertainty – World War II. During WWII, the British Isles were under attack by Germany. England had to develop an effective defense by the efficient use of its scarce resources. A group of individuals including scientists, and mathematicians were assembled to confront logistic problems associated with the allocation of scarce resources (Roush, 2001).

After WWII, the operations research analysts returned to civilian industries. They found the same types of problems and questions about decisions to be made. Those problems included, allocation of scarce resources, scheduling and routing, competition, waiting lines, inventory control, searching, and, replacement and maintenance (Rivett, 1980)

Today, Operations Research is an applied discipline that is a scientific approach to decision making. Such well known tools as linear programming and decision analysis were developed in the discipline of Operations Research. Newer computer and mathematical applications such as neural networks, genetic algorithms, approximate reasoning (fuzzy set theory) and nonlinear dynamics (chaos theory) have relevance to biocomplex problems (Tsoukalas and Uhrig, 1997).

In the early years of agriculture, 50 to 60 years ago, there was really very little need for a structured decision approach in agriculture, in general. A 1% improvement in a $10,000 enterprise would yield only about $100 (Bender, et al., 1976). Today the picture is quite different. In a multibillion dollar business a one percent improvement can mean millions of dollars.

Production Example. Synchronizing Management Decisions - Sadia SA (Taube-Netto, M. ,1996; Roush, 2001)

The Problem

Sadia, a large poultry producer in Brazil, had seven chicken plants each with a near by hatchery. Each plant specialized in different products that required birds within specific weight ranges. Unlike other industrial applications, agricultural businesses have biological variation involved in the decision processes. One of the challenges was to match biological variation of the flocks of individual growers with product requirements. The biological responses and variation of each flock depended on the breed, sex, house construction, competence, dedication of the grower, etc. Critical questions included:

- How many grandparent chicks to order?
- When to replace grandparent and parent flocks?
- Which growers to house flocks?
- When to slaughter the flocks?
- What amount of product to allocate to each processing plant?
- How to match daily slaughter and production capacities?
- How to schedule daily flock pickup with hanging to provide proper weight distributions?

<u>The Solution</u>

The approach used by Sadia, in conjunction with Unisoma (www.Unisoma.com), an operations research company, was to model the business as three different levels of management scope:

1) a strategic module for overall production and distribution;
2) a tactical module for placement, production and sales over time;
3) an operational module for production and sales synchronization.

The Operations Research tools used for the Sadia modules included mathematical programming, econometric models, multivariate statistics, and simulation.

<u>The Value</u>

1) Better feed conversion
2) Improved utilization of the birds to produce more than 300 products classified by weight range, taking into account variation between and within flocks.
3) Almost 10% fulfillment of daily production plans with increases output of high value products.
4) Greater flexibility and reduced lead time in meeting market demand.
5) Timely and wide-ranging studies of different price and demand scenarios.
6) A reported savings of more than $50 million over a 3 year period.

Nutrition Example. Controlling Risk in feed formulation (Roush, Purswell, and Branton, 2007)

<u>The Problem</u>

Uncertainty and risk are inherent in the biological variability of nutrients in feed ingredients. The use of a margin of safety (MOS) was suggested by Nott and Combs

(1967) as a simple way to adjust the nutrient matrix to compensate for nutrient variability. To make the adjustment they suggested subtracting one-half of the standard deviation for the mean value of nutrient. When considering variability, feed formulation becomes a nonlinear problem. Linear programming cannot accurately or precisely meet requested probabilities. The result is that the linear program always over formulates the requested probability (for probabilities greater than 50%). The over formulation also results in a higher cost diet.

The Solution

Stochastic programming is a nonlinear programming approach that can more accurately and precisely meet requested probabilities.

The Value

The use of stochastic programming for feed formulation allows the nutritionist to more accurately and precisely meet requested probabilities. For example, a diet was formulated at a 69% probability using both a linear and a stochastic approach. The linear program using a Margin of Safety approach produced a diet with a calculated 77.26% probability and a cost of $165.78; whereas, the Stochastic program more accurately and precisely met the requested probability at 69% with a cost of $165.34.

Conclusion

Just as biochemistry is a fundamental discipline for nutrition, operations research is a fundamental discipline that defines a structure for poultry management decisions. The operations research discipline includes descriptive, predictive and prescriptive models for allowing a logical approach to making management decisions. Two examples were illustrated. The Sadia company example illustrates the effective use of predictive and prescriptive models within the operations research discipline to optimize products and profit in the poultry industry. The stochastic diet formulation example illustrates how the use of the appropriate algorithm, in this case a nonlinear algorithm, will more accurately and precisely produce desired diet formulation outcomes than the use of traditional linear programming.

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