MARKET EXPANSION POLICY EVALUATION BY SIMULATION

by

R. E. Thiele and R. R. Klimpel
The Dow Chemical Company
Midland, Michigan 48640

I. INTRODUCTION

This paper is concerned with the evaluation of proposed policies for expanding the market of a speciality industrial product and is based on an actual industrial case study. The product under consideration is relatively new and unique with the company holding excellent raw material and technical knowledge positions. While some completely new industrial processes using the new product are feasible, it is anticipated that the major use of the product will be as a replacement for existing products possessing significantly less advantageous use characteristics at a comparable price. Thus, the potential market for the new product is reasonably well known and the problem becomes one of seeking a greater market share rather than creating a strictly new market.

Historically, the marketing and distribution system for this industrial speciality has involved the use of numerous independently owned outlets (often loosely chain affiliated). These distributors are geographically widely spread across the United States and provide the storage and immediate customer shipping and contact work necessary. This is similar to the usual industrial goods outlet handling a wide variety of products (occasionally offering two or more competitive products of the same type). Because of the extreme financial outlay required, the lack of actual customer marketing experience, the lack of a complete speciality product line in this general market, and time, it is not possible for the company to set up a distribution network of its own. Rather, the expansion of the use of the new product must take place by developing contractual relationships with existing distributors. Thus, a technical sales force must be organized and trained to act as the representative of the company to the various distributors (and also to the distributors' customers). By company policy, this route was preferred rather than, for example, the use of manufacturers agents, etc.

The company managers responsible for the new product were, therefore, faced with the problems of planning the new product growth. Questions to be answered were: How many and at what rate should distributors be added (contracted) to the network? How many and at what rate should salesmen be added and trained? What size of production facility is required to maintain future growth? The alternative question is whether or not the company would be better off selling its manufacturing rights to one or more of the existing competitive companies in this market? Due to a number of influences, the time available for such an analysis was short. Whatever study and decisions were to be made, had to be based essentially on existing information which the product managers had previously collected. Taking into consideration the nature of the problem and the data at hand, it was decided by the authors to formulate a straight-forward simulation model containing a mixture of deterministic and random elements. By manipulating this model, the effect of the possible decision parameters could be at least qualitatively evaluated. The simulation system chosen was the recently developed SPURT[1] system (Simulation Package for University Research and Teaching) from Northwestern University. This system is Fortran IV based so that the model could be quickly written in a language familiar to the authors and used on a computer system readily available to us.

II. BASIC ITERATIVE MODEL STRUCTURE

In this section, the basic iterative model equations are briefly outlined with actual data, methods of random selection, model complications, etc., being described in Section III. It is assumed that sales of the new product are increased only by adding new distributors and by increasing the effectiveness of old distributors. Assuming the current year to be t years into the operation, and given a relationship which applies for each distributor giving average sales per year versus years of distributor service, then:

total sales at time t (II-1)

= distributor class 1 average sales at time t ·
Number of class 1 distributors (class 1 would be distributors added during first year of operation)

+ distributor class 2 average sales at time t ·
Number of class 2 distributors

·
·
·

+ distributor class t average sales at time t ·
Number of class t distributors

In order to maintain sales of old distributors as well as introducing new distributors, a highly trained somewhat specialized sales force needs to be developed and maintained. Unfortunately, there is little interchangeability between these salesmen and the remainder of the company's sales force. The hiring and training of these new salesmen is further complicated by a company policy of providing long term stable employment so that large scale lay-offs are to be avoided if possible.

Assuming for the moment that all salesmen are 100% effective salesmen (fully experienced and trained), the time requirements by a given distributor of these salesmen differs according to the experience level (time of operation in dealing with the new product) of the distributor. Thus given a relationship of the number of distributor locations a 100% salesman can handle versus the experience level of these locations:

the total number of 100% effective salesmen required at time t (II-2)

= number of class 1 distributors · average of 2 physical locations per distributor / by number of locations of class 1 distributors that 100% effective salesman can handle

.
.
.

+ number of class t distributors · 2/ by number of class t locations that 100% effective salesman can handle.

However, there is a distinct training period required for a given salesman from the time he is hired (salesmen not 100% effective for a number of years) that can be quantified so that:

actual number of salesmen required at time t (II-3)

= number of salesmen of class 1 (class 1 would be salesmen added during first year of operation) · efficiency of class 1 salesmen / by 100

+ number of salesmen of class 2 · efficiency of class 2 salesmen / by 100

.
.
.

+ (that number of new salesmen · efficiency of new salesmen / 100) necessary to make equation (II-3) an equality with equation (II-2).

Given a relationship between salesman experience and cost:

total cost of salesman at time t (II-4)

= number of class 1 salesmen · cost of class 1 salesmen

.
.
.

+ number of class t salesmen · cost of class t salesmen

Also to a first approximation:

total expense for year t = (II-5)

Total cost of salesmen + sales (lbs) · manufacturing cost/lb + sales (lbs) · transportation cost/lb + sales (lb) · research cost / lb .

and

total profit for year t = (II-6)

sales (lbs) . price received / lb - total expense .

III. DETAILS OF THE SIMULATION MODEL

The backbone of this distribution simulation is the distributor performance data represented in Figure 1. The overall average was taken as the mean of a normal distribution with the high and low averages assumed to lie two standard deviations on either side. Each year a distributor was in the system, his sales were approximated by drawing from the normal distribution representing the sales spread for distributors in his experience group. These annual sales for the system were accumulated using equation II-1. (The lower, poor performance curve approximates the worst expected distributor performance distributions.)

From the number of distributors in the system, how long they have been in service and the fact that each distributor has an average of two locations, the number of 100% efficient salesmen needed to service the system can be found using equation II-2. The horizontal bar with the curve passing through it in Figure 2 represents the midpoint annual value used as the mean. The diagonally lined area in each vertical bar represents the two standard deviation limits on either side of the mean. (Distributors in the system longer than five years are assumed to require the same salesman effectiveness as that during the fifth year.)

To simulate the loss of salesmen, for whatever reason, a simple draw is made for each class of salesmen (i.e., salesmen hired in the same year). The probability of losing a salesman from any class in a given year is an input parameter. The salesmen counts are adjusted as necessary.

Using the salesman efficiency distributions represented in Figure 3, an estimate of the relative number of 100% effective salesmen in the organization is made. These distributions are assumed to be normal with a very small variance. Any salesman in the system longer than eight years is considered to be 100% efficient.

The number of new salesmen needed, if any, is determined by comparing the value of equation II-2 to equation II-3 (the later not including the last term representing the current year). If the difference is positive, it is divided by initial salesman efficiency and that number of new men added to the system as a new salesman class.

In order to take into account the difference in salesmen's compensations, the new salesman class is adjusted by drawings from the distribution in Figure 4. This value is used in conjunction with the data in Figure 5 to calculate sales expense each year for each salesman class.

The raw material costs were calculated in stages. The first increment of raw material is a quantity of byproduct of existing facilities whose level and price are fixed for a given length of time. The volume level, price and duration of further increments are simulation parameters. This and the following supplies are assumed to be available throughout the life of the simulation.

In order to satisfy demands beyond this, two new production plants were assumed. One was of intermediate size (25,000,000 lb/yr.) and the next one of large size (50,000,000 lb/yr.). Both were assumed to have linear economies of scale from the first pound to the last. The cost and production limits are data input to the simulation. Prices and cost are plotted in Figure 6.

The net for the year is determined by multiplying the sales by price and subtracting raw materials cost, sales expense and shipping and research costs. The latter two are assumed to be fractions of sales and the coefficients are simulation input parameters.

Finally the number of distributors to be added and the selling price for the following year are read in and the next annual cycle started. The simulation is terminated after a specified number of annual cycles.

IV. THE CHOICE OF THE SPURT[1] SYSTEM

The primary consideration in designing a computer implemented simulation should be ease of translation of the conceptual model into a computer program while maintaining easy data input, getting controlled output and not sacrificing model realism. The points recommending the SPURT system can be listed as follows:

1. It was written in FORTRAN making it compatible with many computer systems plus easy to augment and/or modify;

2. It contains routines for generation random samples from most of the standard distributions, e.g., Normal, Poisson, Erlang, Uniform, etc. Provision is made for using both discrete and continuous empirical distributions defined by the user;

3. It has an internal clock or timing routine to keep track of current and future events. With the clock, events may be scheduled, bypassed, rescheduled, or deleted;

4. The list processing routines necessary to the clock routine are also available to the user;

5. Several routines are included which accumulate, classify and statistically analyze data. Each has the capability of displaying the results in tabular form;

6. Plotting of histograms is available for either input data or results.

The easy program alteration during the evolution of this model demonstrated the usefulness of points 1 and 2 above. As understanding of the real life system increased during modeling, the changes necessary in the program to reflect this better understanding were made easily and quickly. (As an aside, this is due not insignificantly to the excellent diagnostic messages included in the Burroughs 5500 FORTRAN compiler on which the runs were made.)

V. EXPERIMENTAL DESIGN AND ANALYSIS

In order to analyze the simulation results, a single value representing each run is desirable. Since the model generates annual profit values, an economic measure is indicated. A generally accepted measure of this type is net present value using some specified discount rate. It is outside the scope of this work to justify either the choice of net present value or the discount rate used since the virtues and pitfalls of economic criteria are covered elsewhere in the literature. The nature of the model and the results obtained were felt to be justification enough for this choice.

The annual profits were assumed to have been generated continuously throughout the year. Consequently they were discounted uniformly over the year of generation and instantaneously back to the beginning of the simulation using the following formulas:

$$B_t = P_t(e^r - 1)/r \qquad \text{(V-1)}$$

$$NPV = \sum_{t=1}^{t=n} B_t e^{rt} \qquad \text{(V-2)}$$

where P = annual profit in year t
r = discount rate
e = natural log base
n = years simulated

For the purpose of illustrating typical output data and also indicating the effect of primary factors, several full factorial statistical experiments were carried out and analyzed. Table I lists the factors of an experiment of this type, having three factors, two levels of each factor, and two replicates. The error variation, in this case, reflects the relative effect of the random selection procedure of the primary factors on the output as well as other sources of random behavior implemented in the model. Since an $F \geq 5.32_{1,8}$ for $\alpha = 0.05$ indicates significance, it can be seen that the primary factor levels are important, at least qualitatively, even with the presence of random interaction and fluctuations in the model.

In summary, the results of the simulation indicate that the market expansion possible using estimated raw data under conditions/or policies known and acceptable to the company is financially attractive only if certain conditions can be met. The results are summarized in Table I. The marketing organization subsequently organized to maintain the higher sales price and to operate at a distributor addition rate of at least six per year. At this time it is too early to assess the results of this effort.

[1] Simulation Package for University Research and Teaching, Northwestern University, Vogelback Computing Center, Evanston, Illinois

FIGURE 1
Distributor Performance

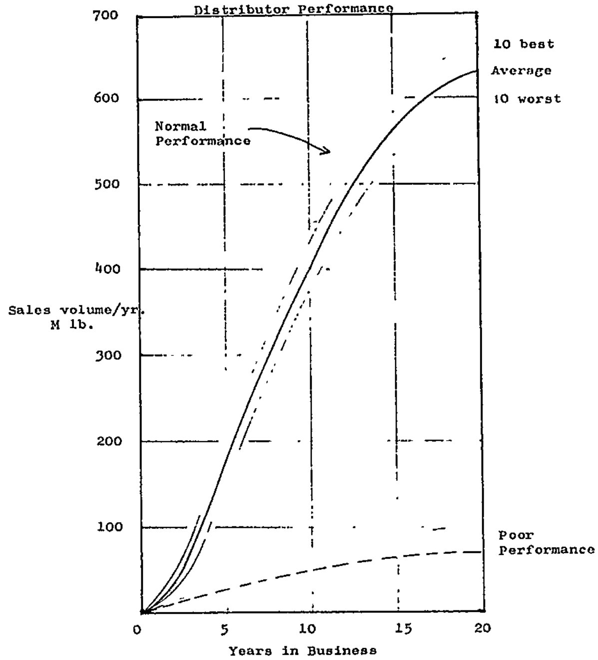

TABLE I

DATA SUMMARY

	A_1		A_2	
	B_1	B_2	B_1	B_2
C_1	-0.933	-0.514	-0.179	1.82
	-0.950	-1.310	-0.555	1.83
C_2	-1.70	-1.33	-0.0743	4.03
	-1.56	-1.30	-0.0490	3.73

ANOVA SUMMARY

Source of Variation	Sums of Squares	Degrees of Freedom	Squares	F
A	25.38	1	25.38	458
B	20.49	1	10.49	189
AB	8.38	1	8.38	151
C	0.40	1	0.40	7.3
AC	2.98	1	2.98	54
BC	1.04	1	1.04	18.7
ABC	0.54	1	0.54	9.7
ERROR (Lumped random elements of model)	0.44	8	0.06	
	49.64	15		

A_1 = Lower sales distribution (distribution performance, Figure 1)
A_2 = Higher sales distribution
B_1 = Lower selling price ($0.17/lbs)
B_2 = Higher selling price ($0.22/lb)
C_1 = Lower distributor addition rate (3/yr)
C_2 = Higher distributor addition rate (6/yr)

FIGURE 2
Salesman Effectiveness

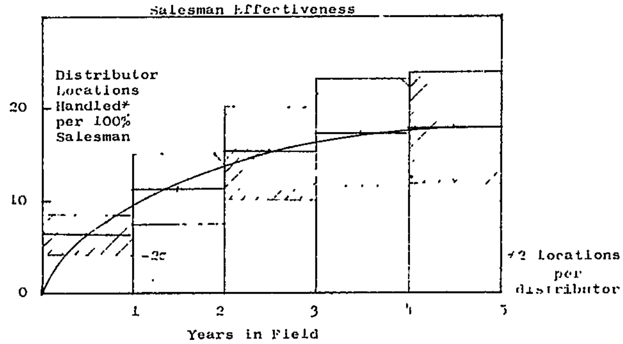

FIGURE 3
Salesman Efficiency

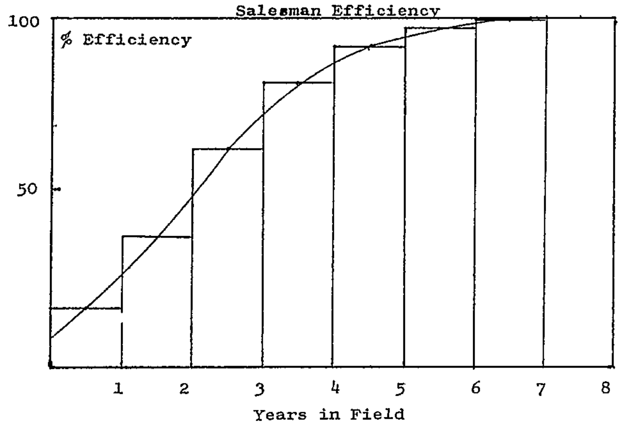

FIGURE 4
Salesman Cost Distribution

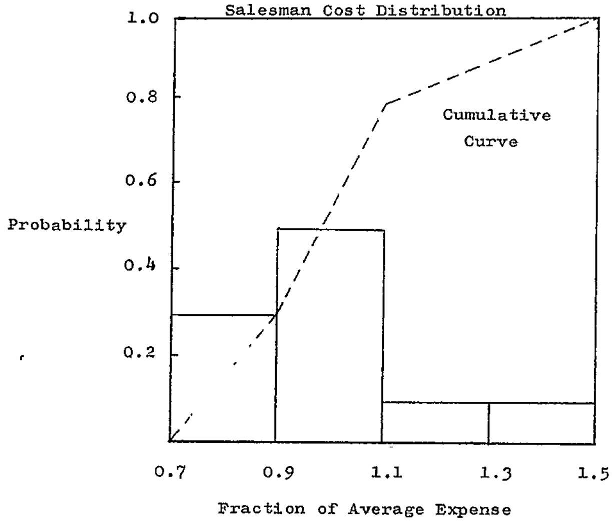

FIGURE 5
Salesman Expense

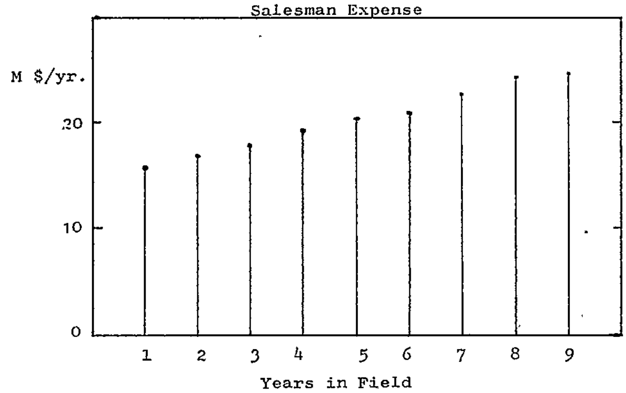

FIGURE 6
Price/Cost Curves