Management Services: A Magazine of Planning, Systems, and Controls

Volume 2 | Number 3 Article 3

5-1965

XYZ Outboard Motor Case

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Operations research is still a frightening phrase to many. But actually it's merely the application of scientific rules which anyone can understand and use to the logical steps anyone would take in solving a problem. For example, take the—

XYZ OUTBOARD MOTOR CASE

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This is an account of an actual operations research study. It tells how the XYZ Company achieved considerable savings through the help of independent consultants in applying operations research to inventory control and ordering. It outlines a practical approach to comparatively routine problems in a small company, which shows that operations research is not necessarily a highly complicated method of solving business problems. Since there have been many articles published recently about operations research theory, there is no need to review its principles here. The exhibit on page 23 briefly reviews what operations research involves.

There are lots of day-to-day business problems that are open to scientific rather than intuitive solutions. By simulating situations in mathematical terms surprising success can often be achieved in solving what appear to be very difficult problems. Furthermore, the sciences of statistics and probability permit approximating the likelihood of something's happening (or not happening) under various assumptions. This is not as complicated as it might seem, as this study shows.

The situation

In the study conducted for XYZ Company, statistical concepts were combined with certain assumptions concerning the important factors in the problem to arrive at solutions for questions that would otherwise have been answered by guessing.

The XYZ Company's president first learned of the potential for using operations research when he outlined a problem with which he was concerned to his consultants during their visit to his plant on

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another matter. His company is a small distributor whose sales approximate $1.5 million annually. The company distributes chainsaws, generators, snow-blowers, and similar gasoline-engine-powered equipment in a four-state region. Its success or failure rests largely upon how successfully it handles the tasks of selling its various lines, controlling its inventory, and ordering from manufacturers.

The problem was a new line that XYZ was entering—outboard motors. It seemed natural for the company to take on outboard motors since the line appeared to tie in with existing sales methods, distribution practices, and facilities. The outboard line promised more than $250,000 in additional yearly volume with only a moderate increase in investment.

Before he committed himself fully to the new line, however, the president recognized that this situation was complicated and decided to look into it further. His discussion with the consultants brought out the following facts which made it apparent that there were both the need and the opportunity for a detailed study of the problem.

Seven phases of problem

First, as the selling season approached, XYZ's president realized that he had no experience in the outboard market. The dealers were marine outlets, which were generally different from those handling the company's other lines.

Second, the outboard motor selling season was a short one. It terminated abruptly about halfway through the summer in the company's market area.

Third, very little existed in the way of records or historical data since the previous distributor had operated pretty much on a "shoe string" basis. The factory did have some data, however.

Fourth, there had been a history of declining sales for this brand, and XYZ learned that the best that could be hoped in this first year was to stem the decline. The company could not expect to increase volume until next year, when its reputation and demonstrated excellence in service and parts deliveries, etc., would be better known to the marine dealers.

Fifth, if XYZ over-ordered, excess quantities of motors left over at the season's end would have to be sold at a discount either in the fall or in the following year. Furthermore, such sales might reduce demand for next year's models, which otherwise might have been sold at a greater profit.

Sixth, there were indications that

Outboard motors were a totally new field to the XYZ Company.

the factory was having trouble making deliveries.

Seventh, if dealers' demands were not satisfied, they might change to competing brands, with serious consequences for XYZ's next year's sales.

This sounds like selling Christmas trees in February or last night's newspaper, doesn't it?

At this point, the selling season had just started and XYZ was in a position either to order heavily in anticipation of sales equal to those of previous years or to "go slow" and approach the season cautiously. As might be expected, the real solution finally proved to be somewhere in between. Reaching this solution first required a more precise definition of the problem these symptoms pointed to.

The problem

In the face of these interacting conditions, the problem was to pick the right quantity of motors for each model in the line so that dealer demands would be satisfied to the greatest possible extent consistent with not having any appreciable stock of units left over at the end of the season. The right quantity would be that which maximized expected profit, weighing potential gains against potential losses. This is precisely the sort of problem to which an operations research approach can be usefully applied.

The approach

Four basic tasks were undertaken in the XYZ case. Actually, they were not too different from the common sense steps anyone would take in any approach to the problem.

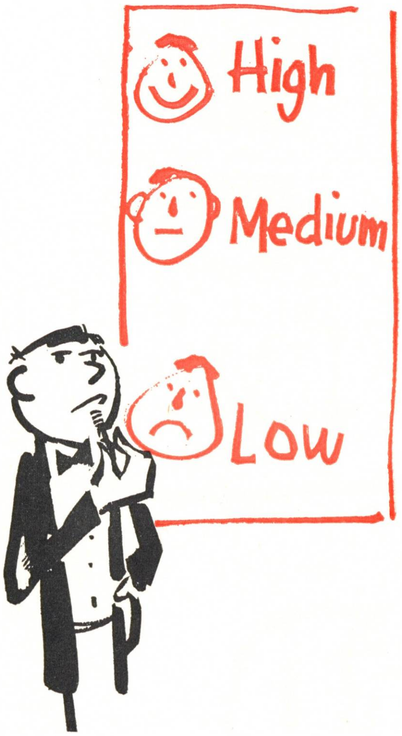
These tasks were as follows:

1. Develop a reliable estimate of requirements (and an inventory policy).

2. Determine availability of stock.

3. Establish up-to-date records covering inventory and commitments.

The problem: Picking the right quantity of motors in each model to satisfy dealer demands while avoiding leftover stock.



4. Prepare for the next year's forecasts.

Let us examine these tasks in detail.

Requirements

The relationship between expected sales (and the profit that could be achieved on those sales) and the possibility of not selling items inventoried in anticipation of sales (and the costs this would involve) was important in developing a reliable estimate of requirements. First, the consultants recommended that the president of XYZ determine what the outboard motor sales were likely to be. This was done by contacting the dealers and then evaluating their replies as described below. Next, the expected profits or "losses" from having motors in stock were identified and taken into account. Finally, an optimum order quantity was determined. The optimum was determined to be the point at which the highest expected profit could be obtained.

Estimating

The consultants suggested to the president of XYZ that he request his dealers to provide him with volume estimates for the various models they expected to sell. He also asked for estimates (covering all models in one total) of:

The lowest quantity they might sell

The quantity they believed they were most likely to sell

The highest quantity they might sell.

This three-level estimating procedure is the key to the rest of the job since it permits mathematical solution of the most important probability aspects, which would be impossible with just a single-level forecast. More about this follows.

The dealers' forecasts were compared with all available historical data. Wide variations were investigated, and adjustments were made where required. Then, using the formulas explained later, the consultants showed the company personnel how to generalize the dealers' forecasts to cover the entire range between the optimistic and pessimistic estimates.

Applying the estimates

The probability of selling any given quantity of units was obtained by assuming that there was no chance of selling less than the pessimistic forecast (A) or more than the optimistic forecast (C) units. The chance of selling was assumed to increase along straight lines (see the insert in Figure 1 on page 19) to a maximum at the point labeled "B." The probability of selling exactly "B" units is equal to $\frac{2}{C-A}$, mathematically speaking, so that the total probability of selling any number of units is equal to one.[1]

Using these assumptions, the probability of selling at least a particular number of units (X) can be found from the following equations:

$$P = 1$$
for any X quantity less than A

$$P = 1 - \frac{(X-A)^2}{(B-A)(C-A)}$$
for any X quantity between A and B

$$P = \frac{(C-X)^2}{(C-B)(C-A)}$$
for any X quantity between B and C

$$P = 0$$
for any X quantity greater than C

Where
P = the probability of selling at least X units at full price
X = the quantity selected for test
A = the pessimistic forecasts
B = the most likely forecasts
C = the optimistic forecasts

A solution for a test quantity of 800 units (using 200 for A, 500 for B, and 1200 for C) is shown in the following example:

[1]The area of the triangle in Figure 1 equals ½(C − A) times the height of the triangle (the probability of selling exactly "B" units). With this area equal to one, solution of the equation for the height of the triangle yields $\frac{2}{C-A}$.

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PROBABILITY OF SELLING VARIOUS QUANTITIES OF MOTORS

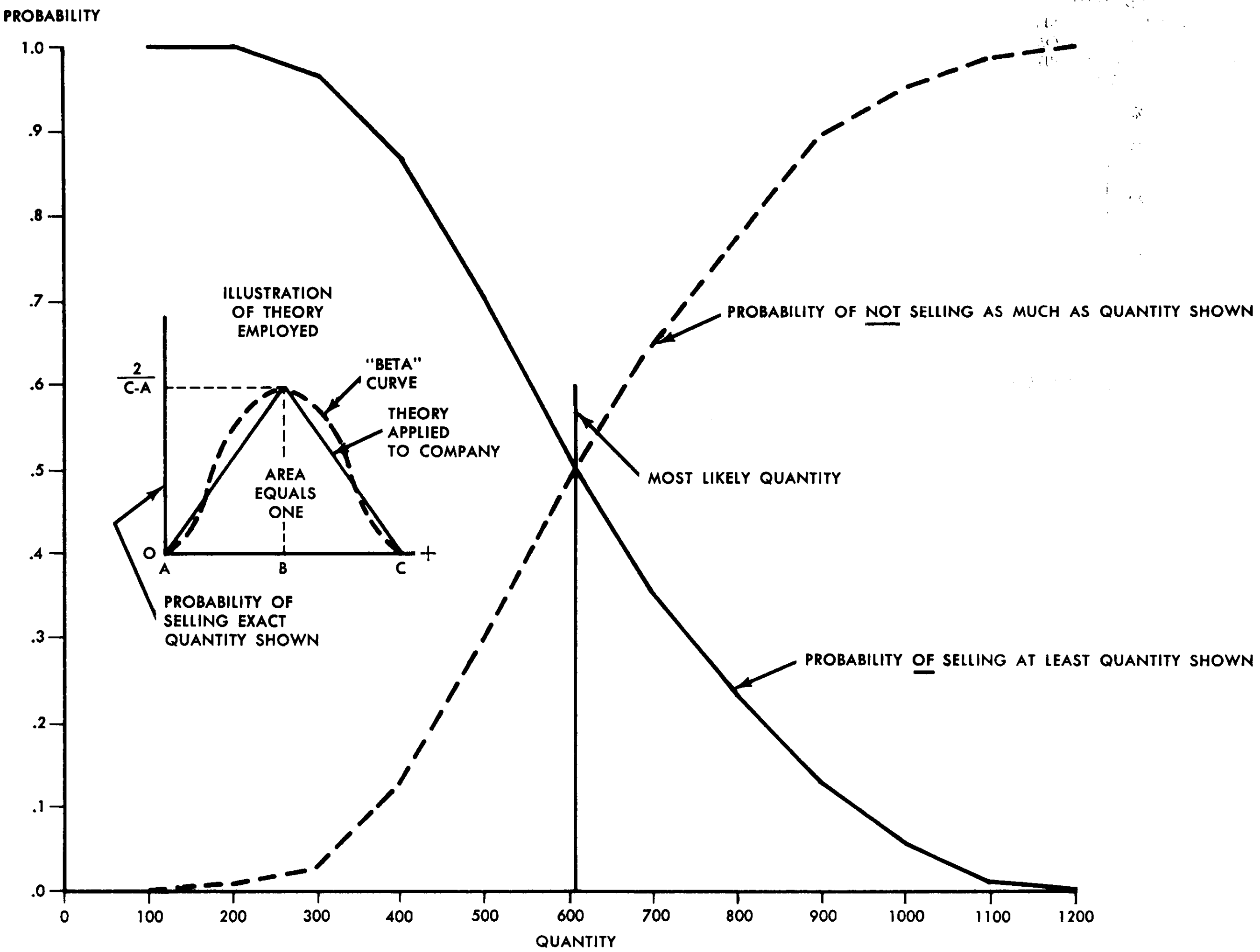


FIGURE 1

$$P = \frac{(1200-800)^2}{(1200-500)(1200-200)}$$
$$P = 22.8\%$$

The average or expected quantity of sales can be obtained by trial and error or by calculation. The expected quantity would occur, of course, where P equals 50 per cent. In this case it works out to roughly 610 units.[2]

This probability information was later combined with the other factors that would affect the buying decision.

Profit and loss potentials

In deciding what quantity to order, the potentials for profit and loss that could be attributed to having a unit in inventory were identified.

Of all the available considerations, the following were selected as being the most significant identifiable factors. The percentages shown are based on selling price to dealers:

Potential gross profit from selling an extra unit........ 15%

Possible markdown on excess quantities (average of markdowns for immediate disposal and for disposal next season) 15%

[2]Another method using optimistic, pessimistic, and most likely estimates is associated with PERT (the Program Evaluation and Review Technique popularized for controlling multi-task projects). This method uses different assumptions to calculate the expected value, as follows:

$$\text{Expected} = \frac{(A\times2)+(B\times4)+(C\times2)}{8}$$

Using the PERT formula would give an expected value of 600 units in the above example. The PERT formula assumes a smooth curve (the Beta distribution) instead of the triangle in Figure 1.

OUTBOARD MOTOR CASE

OPTIMUM ORDER QUANTITY

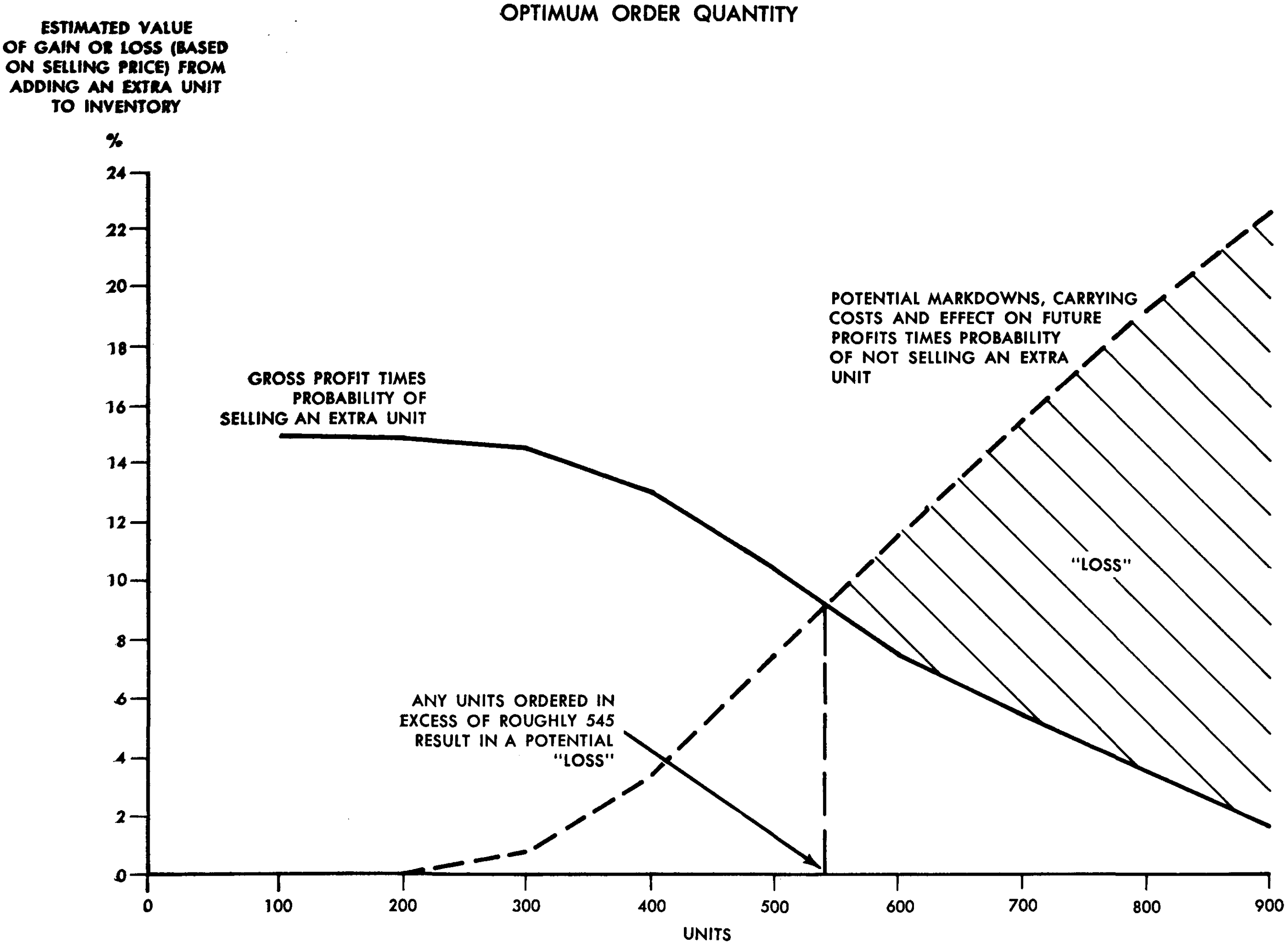


FIGURE 2

Carrying costs (assumed effective average interest rate)* 2%

Effect of excess units on next season's sales** 7%

24%

* One-half of eight months' interest on cost, assuming half of any excess units will be disposed of at the end of the season and half will be held until next year.

** Expected loss of gross profit resulting from lost sales in next year, per unit held over.

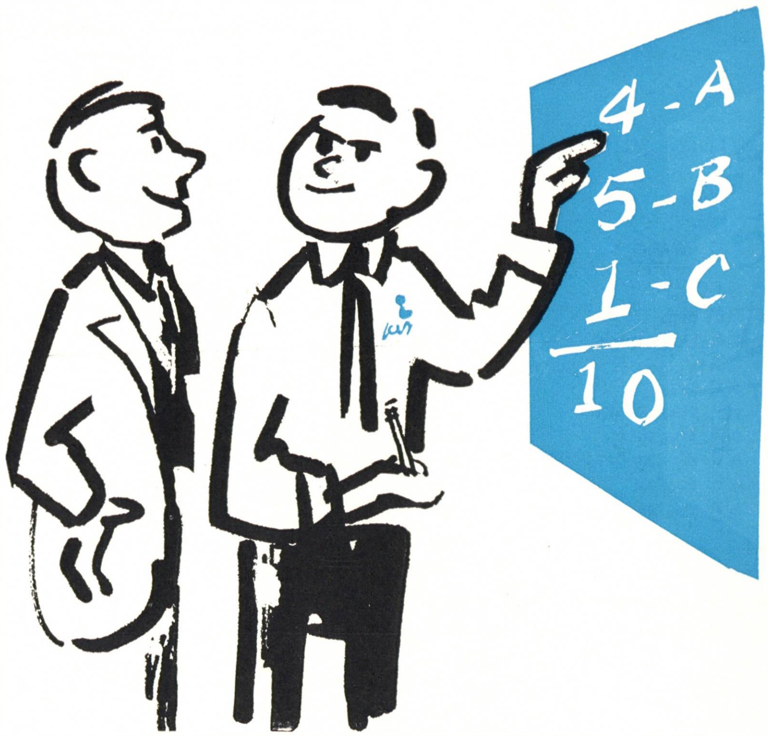
These factors were established by the president's using his current knowledge, general experience in distribution, conversations with the dealers, and data concerning the previous and other distributors' policies (after discussing with the consultants all of the possible factors that could be considered).

Optimum order quantity

The next thing that had to be done was to tie all of these facts concerning estimated sales and profit and loss potentials together into an order quantity that would maximize the expected profit.

Having determined the probabilities of selling various quantities of units and the estimated profit and/or loss effects of holding the extra units, the consultants were then ready to help the company to determine an optimum order quantity. Figure 2 above shows profit and loss for the range of potential orders.

The probability of selling various quantities of units was used to plot the profit and loss lines. The optimum order quantity is found at the point of intersection of the lines. You will note that the slope of the curves is not constant and that the optimum quantity cannot be calculated from the 15:24 relationship of the profit and loss factors without reference to the respective probabilities of selling quantities within the range of orders.



The company asked dealers: "If you could order only ten motors, how would you order them?" This gave percentage projections.

Model mix

With an optimum total quantity established, the dealers' estimates of model requirements were applied to the total. XYZ personnel also applied their judgment concerning current market changes and historical usage (this was the only information that was available from the factory). Approximate requirements for each type of motor were obtained. While the distribution among the models could be no better than the forecasts, the president of XYZ had two things operating in his favor:

1. He would order no more total units than his optimum calculation gave him, and
2. If he erred, he could err purposely on the side of conservatism on big expensive units; he could afford to be liberal with smaller motors. Too much of this could, of course, destroy the effectiveness of the optimum order calculations.

A comparison of the dealers' estimates of the percentages of the various models they would require showed a favorable relationship with the previous experience. "Hot" models were found to be still popular in the current year's line.[3]

Next, XYZ put the information obtained in these procedures to use in determining how many units to order for the rest of the year. The first step was to find out what stock was available.

By this time the outboard selling season had started, and, naturally, XYZ had ordered a number of motors to fill immediate needs. Some of these motors had been sold, and the season appeared to be progressing normally.

Availability

At this point, the president was armed with the data concerning optimum order quantity and model mix described above. He now proceeded to translate his "needs" into actions and place orders or take whatever steps were necessary to ensure that XYZ had the required supply of motors.

This supply of motors could come from three sources:

1. XYZ's own inventory
2. The factory
3. Other outboard motor distributors.

First, the facts as to how many units were on hand and how many units were on order were determined.

A simple schedule was made (see Figure 3 on page 22) which spread all of the available data in columns and simplified order calculations for each model in the line. The schedule shows that ordering to the optimum quantity would require a net reduction in the orders already placed with the factory. This is not all that was done, however.

Availability data obtained from the factory indicated impending shortages in certain models. These turned out to be the "middle-of-the-line" 25-horsepower models and the biggest electric long-shaft model, the very same types in which XYZ appeared to require additional quantities. At this point, the company pressed its salesmen for more intensive action. Instructions were issued to do two things: (a) contact all of the dealers for firm orders based on their forecasts (which added up to more than the expected or optimum numbers) and at the same time (b) try to get the dealers to revise their allocations from one model to another in placing their orders. By revising product mix relationships XYZ hoped to fulfill the highest propor-

[3]The president of XYZ requested the dealers to provide him with percentages, in effect, by asking, "If you could order only ten motors, how would you order them?" This method was easily understood by the dealers and produced estimates that looked reasonable even though some rounding necessarily occurred in a quantity as small as ten. In the aggregate, this rounding effect tended to even out over the various models.

SCHEDULE OF OUTBOARD MOTOR REQUIREMENTS
(Mid-Season estimates)

		Units required			Units available				
Model	Previous year's sales	1964 estimated total requirements*	Sold to date	Remaining needs	Present inventory	On order from factory	Back-ordered units	Units available	Quantity to order (to cancel)
3 H.P.	75	52	25	27	9	25		34	(7)
7.5 H.P. reg.	35	37	22	15	5	12		17	(2)
7.5 H.P. Long Shaft	109	108	61	47	25	32		57	(10)
9.5 H.P.	120	120	55	65	42	20		62	3
25 H.P. reg.	17	16	9	7	1	10	10	1	6
25 H.P. Long Shaft	30	27	15	12	3			3	9
50 H.P. Electric	36	32	15	17	12	10		22	(5)
50 H.P. Electric Long Shaft	77	61	30	31	13	20		33	(2)
80 H.P. Electric	49	43	31	12	5	15		20	(8)
80 H.P. Electric Long Shaft	52	49	21	28	11	15		26	2
Total	600	545	284	261	126	159	10	275	(14)

*Using the optimum determined in Figure 2

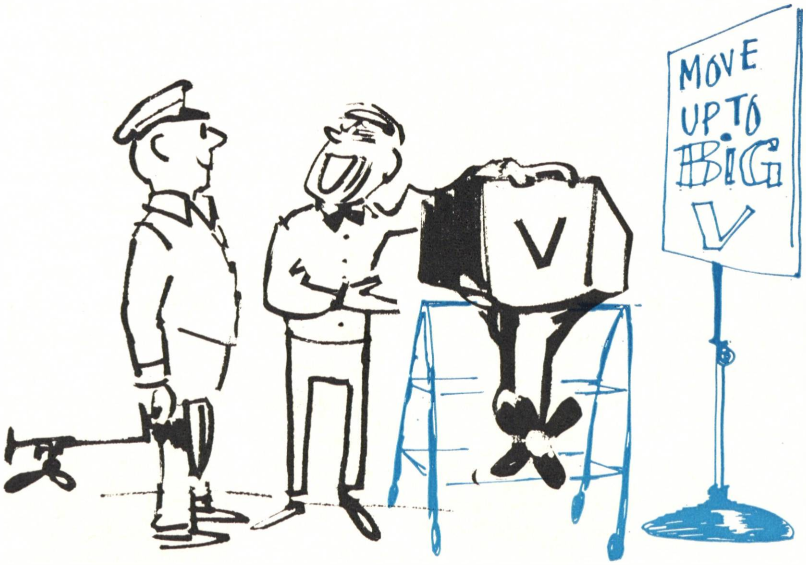
FIGURE 3

tion of the dealers' requirements. Often customers can be upgraded from the 25-horsepower models to, say, 45's, which will do a better job at such things as water-ski towing.

As a result of these steps, the company ended up with fewer "over-ordered" units in all categories. At this point, the president of XYZ could contact other distributors and trade excess stocks, if any. Orders were placed with the factory for units still in production. A rule for handling subsequent orders was established to the effect that orders would be placed for only what could be presold if the resulting total quantity exceeded the optimum.

Dealers appreciated the direct approach, too, since by giving them early notice of which models XYZ could deliver XYZ helped them make realistic promises to customers. As businessmen, they appreciated (but did not wholly agree with) XYZ's basic conservatism.[4]

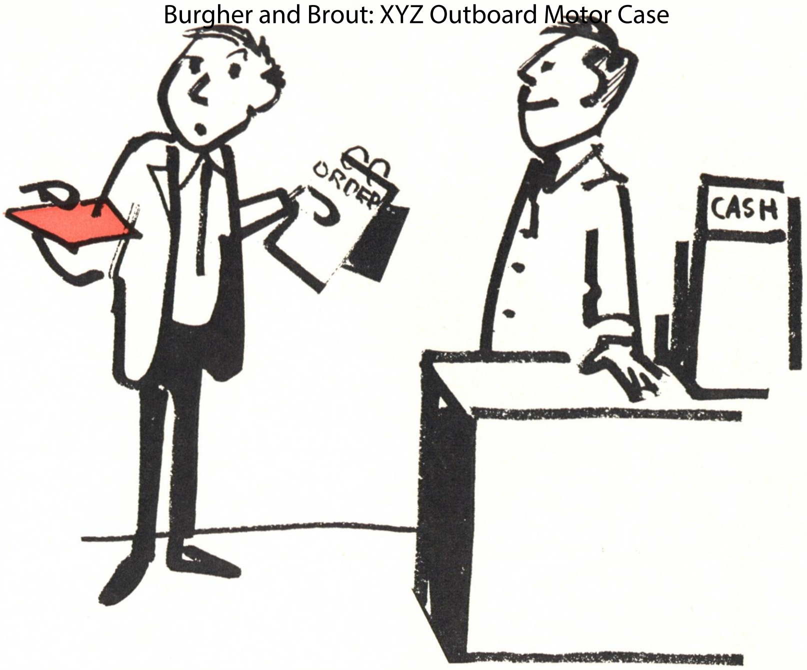
The third major phase of the program was establishing up-to-date records for control over stock and commitments. Other than serial number controls, no records had previously been maintained covering (1) quantities on hand, (2) units on order, and (3) motors available for sale.



Records

A simple perpetual record was designed by the consultants to provide for weekly postings in three sections covering the above data. This record was used for a continuous control over the status of each motor in the line. The consultants also suggested that the president carry a quick-reference pocket-sized card on which the weekly

[4]One thing the president did encourage, in pushing early firm orders, was that the dealers use the "floor plan" method of financing their purchases. Under this method financing for dealer purchases is arranged with a factory-owned financing organization. XYZ guaranteed a fixed percentage of the dealer's indebtedness in return, in effect, for eliminating XYZ's accounts receivable. This eased the drain on XYZ's working capital and enabled the dealers to carry greater inventories at only a small increase in risk to XYZ.



A major phase of the program was establishing good control over quantities on hand, units on order, and motors available for sale.

balances for the three categories would be posted. New postings were made each week. This simplified the president's decision making while he was traveling around with his salesmen visiting the various dealers. The salesmen were also, of course, kept informed of each model's status. These systems and procedures improvements contributed materially to the success of the operations research aspects of the solution.

Scientific study is effective only if carried to working conclusions. Good records (in this case) were the key to making the approach work. Conditions change, dealers fail or are added, the factory changes its output—all of these factors combine to force continual review of the initial optimum order calculations. Therefore, continuing control over the status of the company's inventory and commitments was essential to allow for the changes that were sure to take place.

To illustrate the importance of such control, imagine yourself blindfolded with a bare table in front of you. Someone tosses an eraser on the table without telling you where it is. Try to put your finger on the eraser. Chances are you'll miss it by a wide margin. But, if you are allowed one peek, the eraser will be a lot easier to find. It is this "peek" that such inventory status records will provide.

By continuously monitoring the status of inventory on hand, on order, and available for sale, the president of XYZ was able to watch his entire outboard motor position at all times. When a model seemed to be increasing in supply or, conversely, if one appeared to be all sold out, action was taken to correct the condition.

Near the end of the selling season it became very important to watch the status of each type of motor so that early action could be taken to dispose of any excess quantities. The discounts and carrying costs considered in the profit and

WHAT IS O/R?

Operations research is an approach to problem solving for executive management which is characterized by:

The use of mathematical, economic, and statistical descriptions or models of business problems.

The development of methods or rules to yield measures of the relative profitability of alternative courses of action.

Application to decision-oriented problems in situations of conflict, complexity, or uncertainty.

Analyses of relationships which determine the probable future effects of decision choices.*

*From H. M. Wagner, "Practical Slants on Operations Research," *Harvard Business Review*, May-June, 1963.

The president was supplied with a record, updated weekly, showing stock and commitments for all models of motors.

loss potentials previously mentioned were reviewed so that XYZ could set standards for quick disposal instead of carrying excess units over to the next year. It was economical to clear units out of inventory (assuming the estimates of discounts that might be required a year later were accurate) at any value up to the sum of future discount estimates plus carrying costs. This was preferable to holding such units until the following year when their value might be even less than estimated, when their sale would directly affect demand for then current models, and when the "present value" of having the resulting funds would be less than if the units had been sold earlier.

Preparing for next year

Finally, since the company expected to continue in the outboard motor business, it made sense for it to get ready for the next year's forecasts. A lot of information was generated through the use of the perpetual records mentioned above. For example, both the sales by model and the flow of demand could be extracted from the records.

In addition, the consultants suggested that the dealers' forecasts be compared with their actual performance. Fortunately, XYZ had records that showed dealers' total unit sales, although this data could have been generated by saving and sorting extra copies of shipping notices or sales invoices. (Dealer inventories are a minor factor.)

With the information obtained from this comparison and the factory's estimates of availability and timing, XYZ could be ready with valuable data to help obtain opening orders for each model in next year's line from the dealers.

Finally, the consultants suggested that XYZ should survey the dealers at least twice during the next season so as to have data for "opening" the season and also to have even more accurate forecasts halfway through the season. This second set of forecasts would reflect the effects of any changes in conditions that might develop during the model run. These forecasts would, of course, include pessimistic, most likely, and optimistic estimates. Thus, the entire evaluation procedure should be carried through simply and easily based on this year's experience.

The results of this study were so successful that they appeared to be way out of line with the effort expended. Sales of motors were within a few units of the calculated optimum, and fewer than twenty motors were sold at a discount. Inventories were brought to the desired levels and held there. By the end of the season only the planned number of units (in the popular categories) were on hand to meet anticipated late orders. A gross profit of approximately $50,000 was achieved where there could have been an out-of-pocket loss of an estimated $35,000 to $40,000. The cost of gathering information and operating the inventory records was negligible, and the consultants' fees were a small fraction of the gross profit.

All of this did not happen by accident. The success of the engagement proved to the president of XYZ that careful planning pays off. By working with his consultants he added materially to his effectiveness and insured that the addition of the outboard line was a profitable move for the XYZ Company. And, as a result, the XYZ personnel were trained in the use of a new concept and were provided with working tools they could apply to other products and situations.

It may seem that this case history of a practical application of operations research displays as much application of common sense as of science. This is true. Scientific analysis by itself will not solve business problems—but mathematical techniques when applied with practical imagination can produce significant results. Recognizing the existence of a problem is the biggest part of the job. A bit of imagination will enable you to tackle some tough situations with the assurance that they can be handled successfully. When it is properly applied, operations research can make a significant contribution to management.