SIMULATION AND SALES FORECASTING

by GEORGE SCHUSSEL

Whereas the usefulness of simulation to help solve scientific and engineering problems has been readily accepted for some time, it has only been within the last several years that researchers and practitioners of simulation have developed this technique to the point where it is now readily accepted as a useful tool in the analysis of business decision problems. One of the primary reasons that detailed simulation of the business environment has become practical is because our ability to manipulate and process large amounts of data rapidly has grown fantastically with each new generation of computers.

The field of simulation has grown up to the point where we now see universities teaching courses in it. This substantial growth and interest has resulted in an increase in relevant theory and literature. Within the last five years or so, a new subfield of simulation, called behavioral theory has been developed and expounded by researchers at various universities, notably Carnegie Tech.

Two of the earliest books describing the behavioral theory approach were *A Behavioral Theory of the Firm*[1] and *Portfolio Selection: A Simulation of Trust Investment*.[2] Since these books, other studies have appeared; a recent example is *Forecasting in the Photographic Industry: Testing a Simulation Model*.[3] These studies primarily generated interest among researchers; however, the subject of behavioral theory and human behavior simulation seems to be working its way into the real world as may be attested by some recent articles such as "Heuristic Programs for Decision Making" in the *Harvard Business Review*[4] and an economic commentary in *Business Week*.[5]

A basic premise of behavioral theory is that it is possible and desirable to simulate human decision behavior. Proponents have argued that by simulating human decision behavior it is possible to fuse the worlds of psychology and economics into a new model of economic behavior.

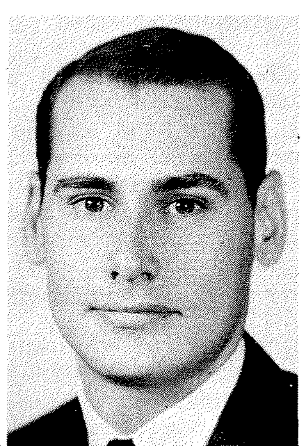
economics and behaviorism

To a large extent, it may be said that conventional economic theory is normative, describing simply logical behavior in a simply logical world. Decision rules which can be derived from this economic theory are those that should be followed by a "rational" being. This view of the world assumes that a person or people in general can prescribe explicit objective functions and proceed on a course to maximize these. In fact, most people, including business executives, are probably not capable of explicitly delineating any objective function; and if they were, they would not have the ability or desire to maximize it. Instead of maximizing an objective function, it can probably be said that most human beings satisfy subjective functions. If this is so, say the behaviorists, then we had better reexamine some of our normative economic models and substitute in their place descriptive models which may then more validly predict economic behavior—at least until everyone is required to obtain a graduate education in operations research.

Pure mathematics, unfortunately, does not generally possess the requisite power to provide a behavioral description or model of human behavior. It may be, however, that the technique of simulation does provide this power. As support for this assertion, this article describes a successful attempt at writing a computer program which was able to simulate some of the decision behavior of retail camera store managers.

the program

This program was written to test the feasibility of simulating the decision behavior of a large, nonhomogeneous sample of people and to test the usefulness to a firm of simulating the external environment in which the firm operated. It was felt that the only valid way to test these points was to construct the simulation in such a manner that it could be used for forecasting. The heart of the simulation consisted of a model that was constructed of the film reordering techniques of 33 photographic dealers. The simulation was constructed to aid a manufacturer in determining the orders for film that would be placed at his warehouse by these dealers. Due to historical experience, the manufacturer had thoroughly good ideas as to what the retail sales of his various film types were; however, he had difficulty in forecasting his own sales because of uncertainty about the way that the dealers reordered film. Because the film product of the manufacturer was



Dr. Schussel is executive assistant to the corporate director of management information and dp at Northrop Corp., Beverly Hills, Calif. Now developing mathematical and economic models for solving production decision problems, he holds MS and DBA degrees from Harvard.

[1] Richard M. Cyert, and James G. March, *A Behavioral Theory of the Firm*. Prentice Hall, Englewood Cliffs, N. J. 1963.

[2] G. P. E. Clarkson, *Portfolio Selection: A Simulation of Trust Investment*. Prentice Hall, Englewood Cliffs, N. J. 1962.

[3] George Schussel, *Forecasting in the Photographic Industry: Testing a Simulation Model*. Unpublished D.B.A. thesis, Baker Library, Harvard Business School, Boston, Mass. 1966.

[4] Jerome D. Wiest, "Heuristic Programs for Decision Making," *Harvard Business Review*. Sept.-Oct., 1966, p. 129.

[5] "The Shake-up of Conventional Economics," *Business Week*. June 25, 1966, p. 186.

very perishable, forecasted sales became an extremely important input to the production scheduling decision.

Even though the manufacturer felt that he could forecast retail sales fairly accurately, his past attempts at converting forecasts of retail sales into forecasts of company sales had proved very inaccurate. From this problem came the idea of interviewing dealers and constructing a simulation model of their behavior which would take a forecast of retail sales as input and then convert this forecast into a forecast of orders placed at the warehouse.[6]

The basic information for the simulation of dealer behavior was derived from detailed field interviewing of the 33 sample dealers in the study. Retail sales forecasts were obtained from company executives and other sources.

In order to test the efficacy of the simulation model, and establish a bound on the accuracy of the model, it was necessary to devise a testing procedure for the model. This test consisted of determining actual retail sales in the five types of film made by the manufacturer for the group of stores over a 15-week period and using these actual sales as input for the simulation model. After the 15 weeks had passed, the output of orders from these dealers was available and, with true sales as input, the basic accuracy of the simulation model was testable. Weekly inventory counting at each store in the study, plus the record of shipments made from the manufacturer, was sufficient to determine the actual weekly retail sales over the period of the study.

Several sales forecasts were generated by different methods. These methods ranged from the simple technique of asking three executives of the manufacturing firm to submit their intuitive forecasts, to the statistical technique of linearly extrapolating seasonally adjusted historical sales data. These sales forecasts were then used in conjunction with the simulation to forecast orders for the 15-week period. Also, in addition to the sales forecasts, several order forecasts were obtained by more conventional statistical and informal means. These order forecasts were used to test the usefulness of the simulation model as a forecast aid. From the results of the study, it was concluded that the order decision processes of certain classes of retail merchants can be simulated. The simulation model performed well when actual retail sales were used as input. It was also concluded that using the simulation in conjunction with forecasted retail sales was the most accurate of the various examined methods of forecasting orders to the manufacturer.

The 33 dealers in this study were placed into two separate samples so that the orders placed by the large dealers would not swamp the ordering of the small dealers. The nine dealers in the large volume sample averaged slightly over 10,000 rolls of the manufacturer's film sold in 1964, the largest dealer selling 20,000 and the smallest dealer selling 5,000. The 24 dealers in the small volume sample averaged 1,500 units in sales in 1964. The smallest sold 340 rolls while the largest sold slightly under 4,000.

The retailers were interviewed in depth about their ordering procedures and, with the exception of the store size in terms of sales volume, the most important distinguishing characteristics of the dealers are listed below.

1. *Having a periodic review, and how often they had it.* Three dealers counted their stock twice a month, four counted it once a month and 21 of the 33 sample dealers didn't use a periodic review.
2. *Ordering constant amounts of film versus having a desired inventory level; and the values of these amounts.* Twelve dealers conceived of the ordering process as one of bringing stock up to a certain desired level; while the other 21 dealers thought of it more in terms of ordering fixed amounts. The actual values varied from as little as 10 units to as much as 400.
3. *Average delay from the time the decision to place an order is made to the delivery of this order.* For 21 of the dealers this was one week and for the other 12 it was two weeks. This delay included the relevant store delays for processing outgoing orders and the incoming shipments.
4. *Types of film carried.* Twenty-five of the dealers carried all five types of film made by the manufacturer. Five did not carry Type 3, two did not carry Type 1, and one dealer did not carry either Type 1 or Type 3.
5. *Regular and emergency order trigger levels on film.* These figures varied substantially with the size and type of dealer, ranging from zero to 200 units as the trigger level.
6. *Batching orders, i.e., whether a dealer reviews and possibly adds to his order other items which are not below their trigger levels, yet are made by this manufacturer.* The idea of batching orders arises because it is very simple to add other items to an order once it is already being placed with a manufacturer. The order is considered a batched one only if it contains some items which would not have been ordered had not an order been placed with the manufacturer at this time. By this definition, 4 dealers batched their orders while 19 did not.
7. *Dealers who tried to order so as to take advantage of the manufacturers' billing dates, thereby picking an extra two weeks to a month of financing on their film inventories.*[7] Eight dealers tried to take advantage of the billing dates, while 25 paid no attention to them.
8. *Percentage of total sales made to industrial accounts.* This percentage varied widely among the different film types in dealers; some dealers had no industrial sales of any types, while others sold 80% of their Type 1 film to industrial users.

Of course there were many other distinguishing characteristics among stores in the study (store type, sales volume, number of employees, etc.). These factors are related to the ones mentioned above. For example, a store with a large sales volume will tend to have high trigger levels and reorder amounts. However, all of these other distinguishing characteristics did not present any meaningful difference with respect to ordering patterns that could not be handled by quantitative descriptions of the above points. In fact, very few consistent clues to ordering behavior were discovered by examination of these more visible characteristics.

The information that was derived from the interviews was used to first conceptualize and then construct the model representation of the manner in which retailers order film. This model explicitly covered all of the above mentioned differences in the dealers and constructed a logical framework for these differences.

The simulation model was programmed in FORTRAN and run on the IBM 7094 at the Harvard Computing Center. The total programming to accomplish the simulation was split into two jobs. The first program (the demand program) took the basic input data, which primarily consisted

[6] To eliminate confusion in the remainder of this article, "retail demand" will mean the amount of film sales requested by customers of the dealers; "sales" will refer to the actual sales made by the dealers. The quantity "sales" is always less than or equal to "retail demand" because of film stock-out conditions. The word "orders" refers to sales of film by the manufacturer to the dealer.

[7] The manufacturer's payment policy was that payment for any order placed between the 25th of one month and the 10th of the consecutive month is not due until the 10th of following month. For example, payment for an order placed on May 28 is not due until July 10. Any order placed between the 11th and 24th of the month has payment due the 10th of the following month.

of the statistics describing gross retail demand, and generated specific forecasted consumer demand per dealer. The second program which was the heart of the simulation, took the demand and simulated the dealer decision behavior.

demand generator

In addition to some secondary chores, the primary purpose of the first program (demand generator) was to take the general sales forecasts made by the executives and break these forecasts down into specific demands for each dealer, for all five film types and for each week. The basic inputs for this program were:

1. An expectation of the way that retail sales would vary over the 15-week period.
2. Factors that assigned what percentages of the entire forecast were to be given to each dealer and each film type. The records of past orders to the manufacturer were the criteria used to determine these percentages.
3. The total forecast distribution of sales for each film type in the period under construction.

The program first generated a figure for the total demand by using a cumulative probability distribution curve for forecasted sales in conjunction with a random number. The actual conversion from random number to sales figure was done by means of a cumulative probability curve. The theory for this is rather simple and is explained on pages 323–325 of R. Schlaifer, *Probability and Statistics for Business Decision.*

The simulation model was constructed so that each dealer could be completely represented by 104 numbers, 29 of which directly pertained to the modeling of the dealer and 75 of which were related to both the modeling of the dealer and the particular period that the simulation was run over. A list of the 29 variables for each dealer is given below.

Basic 29 Numbers for Dealer I

I24ORD(I). One number telling whether the dealer pays attention to the billing cutoff date in ordering.

IDICO(I). One number telling whether the dealer reorders in constant amounts or up to a desired level.

IDELAY(I). One number giving the delay in weeks from an order decision to the time that delivery is received.

IBATCH(I). One number telling if the dealer batches his orders.

TRIGER(I,K). Five numbers giving the basic levels in each film type where the dealer will be indifferent between reordering the film type or not. (50% probability of reordering.)

CONCORD(I,K). Five numbers which are the amounts reordered in each film type by a dealer who views his reordering as being in constant amounts.

DESINV(I,K). Five numbers which are the levels that are ordered up to by dealers who conceive of the ordering process in terms of desired inventory levels.

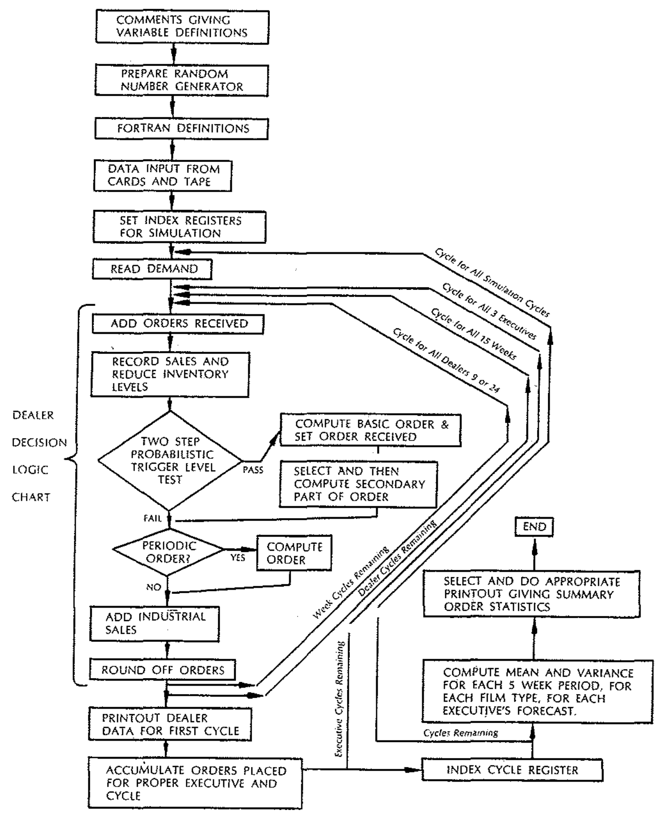
DSINV2(I,K). Five numbers which are the secondary desired levels in each film type. These levels are used in the supplementary part of an order.

The Figs. 1 and 2 are representations of the main program in the dealer simulation.

The Fig. 1 is the general flow chart of the entire program. Fig. 2 is a more detailed chart that explains the dealer logic. It is a representation of the part of the simulation model that emulated the dealer's logic in making his reorder decision.

While much of the programming in the main program was devoted to bookkeeping and other secondary chores, the dealer logic is rather interesting and is partially described below.

Fig. 1



dealer logic

The first thing that the program did for each cycle through the model was to add the amount of film received at the dealer during that period because of orders placed during previous periods.

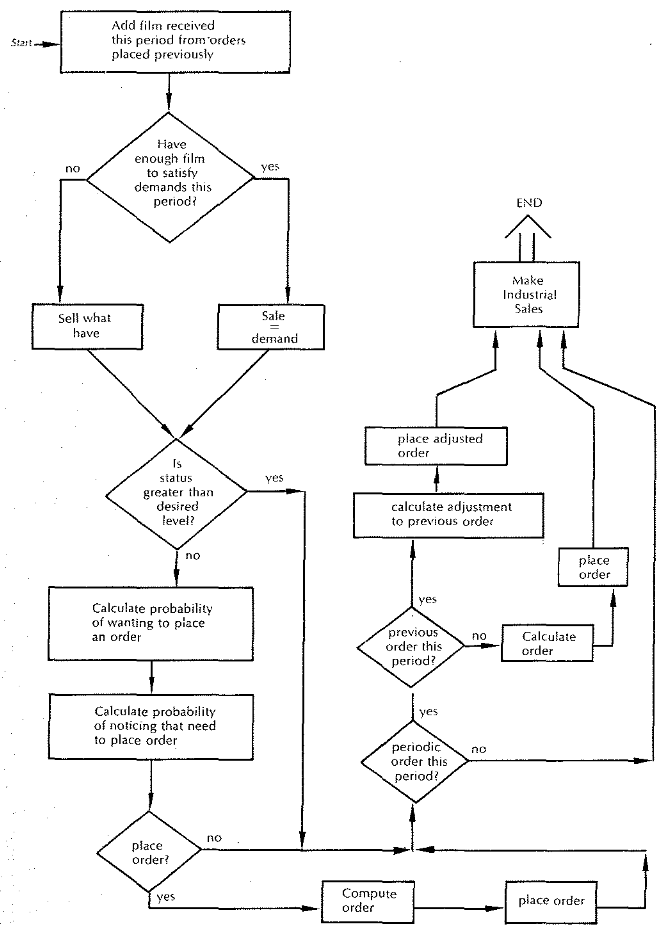
The specific retail demand generated by the first program was next presented and if the dealer had enough film to cover all of his demands, sales equal to the demand were made. If not enough film was available, sales were made up to the level of film in stock.

The trigger level order routine was next entered. All dealers, whether or not they had a trigger level type of reorder system, had a low point trigger which could cause them to order stock. If orders were never placed other than at periodic intervals, then this trigger was considered to be negative.

Where "status" is defined as the amount of film on hand, plus that on order, the program next tested whether the status was greater than the desired inventory level of the dealer. If it was not, then a probabilistic order factor was calculated. This factor was an interpretation of the trigger level questions that were asked of the dealers. The interpretation was that this factor was the percentage "chance" that the dealer would want to place an order if he noticed that a film type was below its trigger level. (Whether or not he noticed will be discussed later.) This percentage "chance" was calculated by linearly interpolating or extrapolating from two known points. These two points were two levels of film where it was assumed the correct corresponding "chance" was known and could be derived from the following conceptualization of the dealer's decision process. The amount of film that was the answer to a trigger level question directed at the dealer was assumed to be the point at which there was a 50% chance of the dealer's wanting to place an order. At zero units of film, the dealer was assumed to have a 100% chance of wanting to place an order. Any amount of film in stock, plus that on order, corresponded to a "chance" that could be calculated by linearly interpolating or extrapolating from these two points. For example, if the trigger level was 20 rolls on hand and on order, then the factor was .75 for 10 rolls, .5 for 20 rolls and .25 for 30 rolls.

Next, a second probabilistic factor was calculated independently of the first. This second factor was time related and could be interpreted as the probability that the dealer would notice that his film stock had reached a reorder point. Dealers tended to order more before a hol-

Fig. 2



iday and this factor reflected this point. On top of this, some dealers paid attention to the payment due date so that they could get added financing on their inventories. More than one dealer was encountered who would not place an order from around the 20th to the 24th of the month.

Therefore, there were two time probabilistic factors: one for the dealer who watched the cutoff date and one for the dealer who didn't. The proper factor was selected and mutliplied by the first probabilistic factor. The rationale for this was that the probability that an order would be placed was equal to the product of the probability that the dealer would notice he needed to order times the probability that he would want to order if he noticed he needed to. A random number was generated and if this number was less than the product of the probability factors, the order was placed.

trigger levels

The actual order placed next depended on whether the dealer was a "desired inventory level" or a "constant order" dealer. The difference was noticed in the interviews, where it was ascertained that some dealers conceived of the ordering process as a bringing of stock up to a predetermined point, where others simply put in an order of a constant given amount (such as 50) of a type when they were below trigger.

Before the trigger level routine was left, a test was made to determine whether this dealer batched his orders. A dealer who batched his orders was simply one who reviewed his other film stock for ordering when he had to reorder one type. If the dealer did not batch his orders, then the trigger level order routine was cycled for all of film types. However, if he did batch orders and an order for one type of film had been placed, then the trigger level routine was left and the batch routine was entered.

This batch routine used secondary trigger levels and secondary desired inventory levels. If an order had already been placed for one type of film, then the likelihood was increased that the dealer would include others that were below their desired levels, although still above the primary trigger levels. Therefore, the seondary trigger levels were higher than the primary trigger levels. When this type of secondary order was placed, however, the amount ordered was usually less than would have been the case if this film had been ordered because of being below the primary trigger. Accordingly, the secondary desired levels were always lower than the primary desired levels.

Perhaps this section might be made clearer by a numerical example. Assume the primary and secondary trigger and desired levels to be as follows:

	Types 1	2	3	4	5
Primary Trigger Level	10	15	10	20	15
Secondary Trigger Level	20	20	20	30	25
Secondary Desired Level	40	60	25	70	60
Primary Desired Level	50	75	30	90	75

If the inventory levels of the dealer were 5, 18, 12, 85, and 31, and the level of the first film type succeeded in triggering an order, then the desired order would be for 45, 42, 13, 0, and 0 units of film. Because this film can only be ordered in multiples of ten, the actual order would be rounded to 50, 40, 10, 0, and 0 units of film. If, because of the random nature of the triggering device, the first film type had not succeeded in triggering the order, then no order would have been placed because no other film type is below its primary trigger. Therefore, for batched stores where a primary order had been placed, the batch routine added an order for any film whose status was below the secondary trigger level.

If no primary order was placed or one was placed but the store was one that didn't batch order, then the trigger level routine was exited from. The next section of the program took care of finishing out the primary trigger order for the dealer. It could have been possible that a level was lower than the trigger and yet because of the random number that was generated, no order for that particular film type had been placed. If an order had been placed in the primary trigger routine, it is only reasonable to expect that any other film that was below its primary trigger would have been added, even if the dealer didn't batch orders. A subsequent section in the program took care of this.

The next section of the program was periodic review. The logic in placing the trigger level orders first was that in the stores that used the periodic order concept the trigger level was an emergency order level which took precedence over regular periodic orders. The first test in the periodic order section was for whether the store had a periodic review that period. If it did not, then the section was skipped. This was always so for stores that did not use the periodic order concept.

If the store did have a periodic order review this period, then the next test was for whether an order had already been placed because of a trigger. If no order had been placed, the periodic review was completed. The order was calculated according to either the constant order or desired level policy and it was placed. If an order had been placed, then the next test was for whether all of the film types were ordered. If they were, the program proceeded to the next section. If some film types had not been ordered this period, then the program entered a section which calculated a supplemental order section, if necessary, to the one that had already been placed.

orders and output

This supplemental section was necessary because if this dealer regularly ordered only at periodic intervals and a partial order had already been calculated for him in this period, then the model had interpreted this partial order as an "emergency" order to fill in the dealer's stock until the next regular reordering period. Since now the model became aware that this was the regular ordering period, the amounts formulated as an "emergency" order for this period were converted into the regular amounts that would have been ordered in a regular periodic order. The supplemental section did this conversion. Since all of this happened in one time period, the "emergency" order and supplemental order showed up as one order.

The program took care of the dealer's industrial sales after the periodic review section was over. These industrial sales were different from ordinary sales in that they were usually made to a relatively small number of customers who called infrequently and ordered rather large amounts of film at a time.

The rest of the program consisted of certain bookkeeping operations, output and the statistical section which computed the basic statistics on sales and orders that were of interest.

The main part of the program was cycled through four different cycle indexes: the number of dealers, the number of periods (15), the number of executives who had made forecasts (3), and the number of simulation cycles. Because of their interactions, the five film types were taken care of interdependently on each cycle. The other four factors, however, operated independently and therefore could be handled by cycling. From the innermost to the outermost, the central part of the program was cycled for all dealers, then all periods, then the executives, and finally the simulation cycles (which, along with random numbers, introduced the distribution aspect to the outcomes).

The final output from the simulation was a single page giving the mean and standard deviation of the total orders placed with the manufacturer for each of the three five-week periods in the study. A typical output page is presented in Fig. 3.

There were many items besides sales and orders that could be calculated from this program: average inventory levels, fluctuations in inventory, lost sales due to stockouts, etc. However, these were not of immediate interest to the point of the research and therefore the only printouts concerned the above points.

conclusions

When the accuracies of all of the forecasts made by other methods were compared with the accuracy of the forecasts made by using the simulation, the very obvious conclusion was that the simulation method was substantially superior. The methods were ranked by two statistics, absolute and squared deviation, for both dealer samples.

Fig. 3

SAMPLE OF 24 DEALERS

IMPLICATION OF SALES FORECAST BY JONES

	FIRST FIVE WEEKS			SECOND FIVE WEEKS			THIRD FIVE WEEKS		
	TOTAL ORDERS		SALES	TOTAL ORDERS		SALES	TOTAL ORDERS		SALES
FILM	MEAN	STD. DEV.		MEAN	STD. DEV.		MEAN	STD. DEV.	
1	836.	149.	551.	447.	121.	458.	461.	148.	492.
2	1786.	262.	1716.	1336.	315.	1351.	1822.	340.	1835.
3	470.	74.	406.	316.	94.	325.	377.	85.	387.
4	1774.	209.	1420.	1139.	252.	1122.	1349.	247.	1411.
5	1442.	264.	1332.	1066.	249.	1052.	1214.	297.	1239.

IMPLICATION OF SALES FORECAST BY SMITH

	FIRST FIVE WEEKS			SECOND FIVE WEEKS			THIRD FIVE WEEKS		
	TOTAL ORDERS		SALES	TOTAL ORDERS		SALES	TOTAL ORDERS		SALES
FILM	MEAN	STD. DEV.		MEAN	STD. DEV.		MEAN	STD. DEV.	
1	868.	82.	543.	332.	84.	367.	363.	68.	385.
2	1918.	83.	1896.	1270.	139.	1148.	1465.	173.	1608.
3	404.	25.	303.	128.	37.	200.	291.	51.	241.
4	1800.	142.	1451.	1021.	201.	1013.	1216.	207.	1290.
5	1113.	89.	1034.	756.	108.	687.	799.	106.	831.

IMPLICATION OF SALES FORECAST BY MURPHY

	FIRST FIVE WEEKS			SECOND FIVE WEEKS			THIRD FIVE WEEKS		
	TOTAL ORDERS		SALES	TOTAL ORDERS		SALES	TOTAL ORDERS		SALES
FILM	MEAN	STD. DEV.		MEAN	STD. DEV.		MEAN	STD. DEV.	
1	918.	92.	601.	389.	90.	439.	447.	83.	470.
2	1959.	117.	1929.	1398.	160.	1307.	1697.	257.	1785.
3	434.	44.	359.	234.	83.	262.	324.	66.	314.
4	1747.	249.	1355.	845.	168.	890.	1138.	180.	1153.
5	1096.	161.	992.	762.	178.	721.	835.	199.	870.

The simulation method had substantially smaller deviations. For example, in the four cases of the two dealer samples ranked by the two statistics, every executive's sales forecast operated on by the simulation was superior to the straight forecast of orders made by the same executive.

Unsophisticated retailers seem to have a sufficiently systematic set of procedures to permit simulation of these procedures by a computer model. This is not such a surprising conclusion, since we would expect successful dealers to have a rationale for their actions. Those that do not have rational (not necessarily sophisticated) patterns of business behavior have probably gone out of business. For many products, these procedures may be determined by interviewing retailers. There is nothing particularly abnormal about film that would lead us to believe that we can successfully model the reordering of film and not of other products.

Considering all of the results that were derived from the study, it was concluded that a behavioral simulation model of the type constructed can be useful in the analysis and prediction of retailer behavior. More generally, we can state that a behavioral simulation model can be useful for analysis or forecasting in marketing problems where one tries to simulate the external environment of the firm. Whether the simulation approach is the correct one, in terms of cost justification, depends on the specific problem area.

There were many particular characteristics, both of the market place and of the particular product line that led to the model developed in this research. However, these were not requisite characteristics for developing a simulation model of the reordering process. For example, if film were heavily promoted, a section in the simulation model could have taken this into account. By definition, if one wishes to simulate a process, he must model the special characteristics of that process. Just because another process does not possess those characteristics, does not mean that it can not be modeled likewise. It does mean that the model constructed for the first case probably will not fit the second.

A simulation model of the type that was constructed for this research could also be useful in experimentation leading to a better understanding of the market environment. One variable could be changed, while the rest are held constant and variations in the output could then be compared with the changes in the input variable so that a better understanding of the environment can be obtained. For example, a step function of sales could be arbitrarily introduced, so that the resulting ordering pattern could be studied. Sensitivity tests would also be possible. If a change in corporate policy affecting dealer ordering was being contemplated, this change could be programmed into the model and the effect on the forecast of orders generated by the model could be studied. This type of information could be valuable in corporate decisions.

Because the primary purpose of the study was to examine the ordering process which acts as a transfer function between retail sales and wholesale orders, little attention was paid to the factors not immediately relevant to this transfer function. It is obvious, however, that any improvements that can be made in retail sales forecasting would improve order forecasting. As a matter of fact, the results of the research suggest that by using behavioral simulation, the transfer function between the retail sales and wholesale orders is tractable and that further work should be in the area of forecasting retail sales. ■