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An evolutionary methodology is proposed to encourage successful implementation of management science models. An example is presented by a series of new product models.

Evolutionary Model Building

INTRODUCTION

Although there are sophisticated management science models, very few complex ones have achieved continuing use. The problem of implementing these models is significant and will become more difficult as even more complex management science models and information systems are developed. Difficulties that will occur include: (1) gaining management attention, understanding, and support, (2) limited availability of data to support models, (3) high risk because of large fund commitments, and (4) long model development periods, which do not allow demonstration of short-term benefits. The introduction of models as an evolutionary development from simple to more complex but related ones would foster managerial acceptance, encourage an orderly development of data and analysis systems, and reduce risks of failure. These models and their benefits will be discussed here by using SPRINTER, a set of on-line models for evolutionary use in analyzing new, frequently purchased consumer goods.

EVOLUTION OF MOD I

SPRINTER Mod I describes the acceptance process of a new consumer product through trial, repeats, and loyalty. Customers are classified by product use experience. Potential users are in the trial class. When they first buy, they move to the preference class, where at the next purchase opportunity they either repeat and move to the loyalty class or do not and return to the trial class. Those who repeat in the loyalty class remain in that class, while those who do not are returned to the preference class. The parameters are the trial rates per period, first and second repeat rates, and frequencies of purchase. The distribution of purchase frequencies specifies the time between purchase opportunities.

This is an extremely simple model and, with a given set of trial and repeat rates and purchase frequencies, it can be used to predict sales and profit in each period. Mod I is basically a specific statement or translation of the implicit model used by many new product managers. The interaction between the manager and the model is facilitated by its implementation in an on-line conversational program. In this way the manager feels he has control of the model and it is his. Although the computer model is a translation of the manager's model, it is a little more explicit in consideration of purchase frequency and trial rate changes over time. The computer model also allows the manager to try quickly many alternate sets of input to generate sales forecasts. The data needed for Mod I could be subjective, based on pretest product use studies, appeal tests, or comparisons with past products. However, panel data from test markets could be used to estimate empirically trial and repeat rates.

The simple Mod I model can be extended by the behavioral science option. In this Mod IBS model, the trial rate is divided into processes of gaining awareness, developing intent to try (given awareness), and finding the product. The added inputs are the percent of people aware, the fraction of those aware who state a predisposition to try the product, and the percent of product availability in each period. The trial rate in a period is the product of these three fractions.

The basic contribution of the behavioral science option is a better understanding of the process of trial. It separates the effects of advertising budget, appeal, and distribution. Awareness changes depend on budget changes, intent rates on the appeal effectiveness, and availability on the extent of distribution. Mod IBS could be run on subjective data, but it would probably require collection of test market awareness questionnaires, to

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measure specific recall of ads and predisposition to try [4]. The behavioral science option usually extends the manager's implicit model, by emphasizing the consumer decision process, which he usually finds intuitively appealing and understandable. Mod IBS also extends data needs by requiring awareness, intent, and availability parameters. It produces a sales forecast but begins to set the framework for looking at changes in strategy. For example, awareness could be changed to reflect a greater budget expenditure, or availability could be changed to reflect a different introductory middleman deal [2].

EVOLUTION OF MOD II

Mod II explicitly faces the issue of finding the best strategy for the new product by linking controllable variables of price and advertising to the diffusion process. It further extends Mod I by considering trial and repeat processes in significantly more detail. In the first instance, Mod II includes specific awareness levels, in-store brand selection, and forgetting. In the second instance, the repeat process in the preference class is broadened from one aggregate repeat rate to a series of steps in Mod II. The repurchase process here is one of gaining awareness of product characteristics through usage, developing preference, formulating intent, finding the product, and selecting the brand in the store.

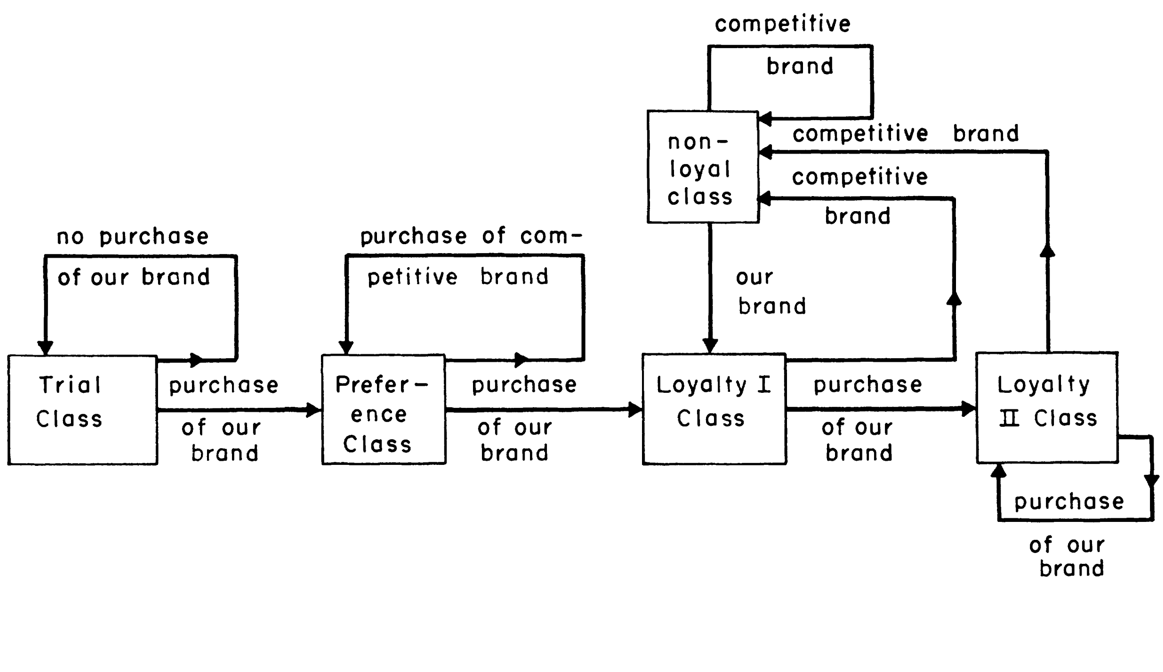
Trial experience may be negative, so in Mod II those who have a negative opinion of the product are segmented in the preference class. If they do not repeat, they are not returned to the trial class, as in Mod I; rather, they remain in a negative opinion state. Nonbuyers in the loyalty class are also segmented in Mod II (class definitions are in the figure).

The trial class contains members of the target group who have not tried, and who gain awareness as the result of advertising. In Mod II advertising response functions are explicitly stated as the percent made aware by a particular advertising expenditure. Overall awareness is segmented into four specific awareness states, defined as: (1) unaware, (2) aware of brand only, (3) aware of ads and brand, and (4) aware of specific advertising appeals.

The rate of intent in each awareness class is used to determine the total number of people with intent to try. Those with intent look for and find the brand in proportion to its availability, after which some fraction will buy it. This fraction is a function of the price of this brand relative to that of the competitive brand. Those with no intent also go through the in-store process, and some may buy the product because of point-of-purchase activity. Those who purchase move to the preference class; those who do not buy experience forgetting; they move from higher to lower awareness classes and remain in the trial class.

Those in the preference class are categorized, on the basis of awareness resulting from usage experience and advertising effects, in the following states: aware of brand only, aware of ad appeals but no definite opinion, positive opinion, and negative opinion. Here, degrees of awareness depend upon trial results, but are also a function of advertising since advertisements can affect perception of brand characteristics. Since all consumers do not purchase during each period, a distribution of purchase frequency is used to place triers from the last period into holding classes. Only those ready to purchase some brand in the product class in the particular period are moved through the preference, intent, and choice process. Those in each awareness state are rated in terms of first and second preference for our brand and these

MOD II PRODUCT EXPERIENCE CLASSES



rates are used to find the total number with first preference, second, or no preference. The number of people with intent to repeat depends upon the fractions of those with first, second, or no preference who display intent. These fractions are made functional upon our advertising relative to that of competitors.

In each preference state, the number with intent is the fraction of those who intend to repeat times that preference state's population. Those with intent who return to the same store where they first found our brand will usually buy it again; otherwise, they find it in proportion to its overall availability. After finding, some fraction of those with intent will exercise it in any store where the product is found. This fraction is a function of our price relative to that of competitors. Some fraction with no intent may also repurchase because of point-of-purchase display. Those who buy move to the Loyalty I class while those who buy another brand stay in the preference class. Those who buy again move to the Loyalty II class.

The number of buyers who purchase in a loyalty class is simply determined by multiplying repurchase probability by the number in the product experience class ready to buy. In the Loyalty I and II classes, however, the fraction of people repeating is a function of advertising and price relative to that of competitors. For example, a substantial deal or advertising campaign by competitors may even reduce the repurchase rate of those who have used our brand two or three times consecutively.

The Mod II model, given a price and advertising strategy for our brand and its competitors, will generate a sales and profit forecast. In Mod II there is a SEARCH option so that a combination of strategy alternatives can be evaluated. For example, three prices and five advertising levels could be evaluated in all combinations to find the strategy that gives the greatest total discounted profit over a planning period. After these alternatives are reviewed, a new set can be generated so that the manager can iteratively proceed until he finds a good or best strategy. Mod II also permits a probability distribution assigned to the sales level, so the probability of achieving a payback or rate of return objective can be calculated. These calculations are useful in evaluating the risk-return balance in a GO-ON-NO decision for the brand.

The extensions from Mod I enable Mod II to make a number of new contributions, most importantly linking strategy variables to the process. Along with the risk output of Mod II, this normative capability helps give a more analytical approach to the GO-ON-NO decision. Mod II adds a significant amount of new detail to the process description to promote a more complete and exact understanding of the diffusion process. This is useful in diagnosing problems, generating revised forecasts, and finding new best strategies. The adaptive control is especially important in early national introduction. Mod II represents a real extension and improvement over most existing analytical procedures, but it evolves these new capabilities from the implicit and existing procedures of Mod I.

While Mod II adds new meaningful detail to the process and supplies the SEARCH capability, these extensions require new data and more analysis. Mod II needs store and media audits and consumer panel data, in addition to the awareness questionnaires of Mod IBS. But the most demanding new inputs are the functions linking the variables to the process. These may be obtained by examining differences between prices in stores or advertising between cities or over time, but the best method is to use experimental design. The results can be monitored in the awareness, point of purchase, and usage data, which when analyzed by statistical methods yield estimates of Mod II's parameters [3]. Mod II's data needs are relatively large, but each bit is interpreted and used, so the data encourage empirical learning about the process. The model's capability to effectively use test market data is an important reason for its existence, where without a model data tend to be aggregated and used ineffectively.

EVOLUTION OF MOD III

SPRINTER Mod III continues the evolution by adding more variables, more detail in the process description, and new behavioral phenomena. In Mod III samples, coupons, point-of-purchase displays, shelf facings, middleman deals, and the number of sales calls, as well as price and advertising, are included as controllable variables. The most significant new behavioral process is the exchange of word-of-mouth communication. This process is structured by determining how many users recommend the product and how many nonusers request information. If the information is transferred to a nonuser who is not aware of the content of the personal communication, he is moved to the higher awareness state.

The space between Mod II and Mod III is not empty. Customized models incorporating some of the Mod III extensions can be structured on-line as a manager selects appropriate options through the continuum between Mod II and Mod III.

The data needs of Mod III and Mod II are similar except that larger sample sizes are needed to separate the new effects and more experimentation is needed since more variables are included. New data are also needed to monitor word-of-mouth exchanges, and sales call reports are required to parameterize the submodel that describes growing availability. More depth is required in monitoring competitive interaction data for Mod III since it models at a higher level of detail.

Mod III is currently the final model in the evolutionary SPRINTER series and is evolved from the simplest implicit model to one with eight strategy elements, a disaggregate definition of structural components, and a high level of behavior process detail.

EVOLUTIONARY USE OF SPRINTER MODELS

The major benefit achieved by evolutionary use of Mods I, II, and III models is that since each model is designed to be a reasonable step from the previous one, managers are able to understand the structure and be convinced of its face validity. The managers' evolutionary acceptance and understanding is a key to the continuing use of models and the improvement in new product analysis. The managers must feel that they are masters of the models and that they are not losing control of decisions.

Another benefit of evolutionary use is an orderly development of the data collection and analysis support system. As movement is made from one model to the next, data specification and statistical capabilities can be more efficiently developed, which, in turn, permits movement to Mod II and Mod III where the normative advantages of strategy recommendation and adaptive planning can be tapped. Initial experience with Mod III indicates that profits can be increased substantially by using these capabilities. Greater profits and the model's explicit risk output allow a more analytical GO-ON-NO decision that in the long run can reduce new product failure rate.

An important advantage of evolutionary models is that marginal costs and benefits can be compared at each stage of the project, which reduces the risk of failure. Modeling projects usually aim at fairly complex, sophisticated end-product models. However, in an evolutionary system there is no need to commit a large amount of funds to the final model unless the initial evolutionary models prove to be attractive on the basis of their costs and benefits. Thus, the evolutionary approach further reduces risk in the new product example since, if Mod I or Mod II does not achieve its objectives, the project can be aborted without expending the total Mod III project budget. The risk of failure due to lack of continuing use of the models is also reduced, since during evolution, management learns more about use of the models and collection of data.

The table gives the per product data collection and analysis costs and the model acquisition cost ratios for SPRINTER. These costs of the evolutionary modeling system must be compared to those of a single effort directed toward the desired final model. For an integrated set of models, the only added data costs are for data collected at one stage but not required at succeeding stages. Such costs can be minimized in a carefully designed series of models. However, if evolution is through a set of less closely related models (e.g., a stochastic brand-switching model to a math programming optimization model), data may not be completely compatible.

ESTIMATED COSTS

Item	*Mod I*	*Mod II*	*Mod III*
Data collection cost (estimated thousands of dollars)	0–10	25–50	50–75
Data analysis cost (thousands of dollars)	0–5	10–15	15–25
Model acquisition cost ratios	1	3	5
Computer run times per iteration (SDS940 computer and 36-period iteration)	1 second	10 seconds	20 seconds

The acquisition cost ratios in the table reflect a split of development cost between multiple users, since these models are implemented in a model utility. The total development cost is probably a little greater than that of a Mod III level model initially. However, the evolutionary plan can reduce development cost in some situations, since the model builder learns to allocate additional detail as he develops the first models. He also learns to understand the manager's needs more fully, and the atmosphere of mutual understanding important in implementing models is improved. We feel that the small additional development cost, if it exists, is vastly overshadowed by the benefits of evolution.

A final benefit of evolutionary systems is their ability to demonstrate short-run rewards. The first model may be available relatively quickly—about six months for Mod I—so the project can show some benefits early. It may take longer to reach the potential point of application for the desired final model under an evolutionary program, but not to reach the time of continuing use of the model. We feel that the constraint on progress in model application is achieving management's understanding, and that the evolutionary adoption of a set of models will speed this educational process. With the increasing commercial availability of models on time shared computer utilities, the modeling effort will not be limited by software development, but can evolve as fast as managerial understanding and data availability permit.

Even if management and data were initially ready for Mod III, Mods I and II models might be needed in new product analysis, because decisions are sequential. First, a decision is made to test market the product. At this point not much data is available, so Mod I is appropriate to examine sales and profit results in the test market. In fact, Mod I has been found to be very useful in developing a compatible set of awareness, trial, usage, and repeat rate goals for test markets. As early data arrive, or if a "mini-test" is conducted, Mod II might be more appropriate than Mod III. Mod III might be too costly if the product has small expected sales volume, so Mod II might be used. The choice of Mod I, II, or III models might also depend on a particular manager. If his style is less analytical, he may feel more comfortable with Mod II rather than Mod III. The choice will depend on the product's stage in the decision network, management's level of understanding, and cost-benefit tradeoff.

CONCLUSION

To demonstrate the usefulness of the evolutionary model building concept, we have discussed a set of three evolutionary models for analysis of new, frequently purchased consumer goods. These models evolved from a simple predictive process flow model with four parameters to a complex normative behavioral process model with over 50 parameters. Evolution proceeded along the dimensions of level of detail, number of variables, and quantity of behavioral process content. The advantages of this evolutionary approach are: (1) increased managerial understanding and acceptance, (2) orderly development of data base and data analysis capability, (3) opportunity to make marginal cost-marginal benefit analyses, (4) reduction of project risk by the availability of abort opportunities at marginal analysis points, (5) learning by model builders about the level of detail for the model and about managers, and (6) availability of short-term benefits.

These advantages encourage efficient system design and continuing use by managers. Although cited relative to a specific series of models, we feel these advantages can be generalized to many other model-based system projects in other decision areas, as in [1].

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