PRODUCT PLANNING DECISION*

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THE "PRODUCT" AND COMPETITIVE STRATEGIES

In the preceding sections of the book various marketing mix elements such as price, advertising, personnel selling, and channels of distribution have been analyzed and discussed. In this chapter these parameters will be considered with design factors and competitive strategies in the analysis of the "product."

The "product" is the total bundle of utility generating characteristics associated with the physical good. The physical design and quality of the good are the most elementary characteristics of the product since they underly the basic utility the consumer ascribes to the good, but the other marketing mix elements are also important. The price associated with the product helps determine its utility level relative to other products. In this way, the price level affects the proportion of the consumer's income he will allocate to the product in his overall utility maximization. Advertising serves to communicate the product attributes to potential purchasers. It demonstrates to the consumer how the product can fulfill his needs and, in some cases, it may produce changes in the utility level associated with filling particular needs. Personal selling similarly serves to convince the consumer of the potential satisfaction the product will produce. Channels of distribution are another element in the definition of the product, since they create the time and place utility for the product by making it available in adequate quantities at the time of purchase. These considerations complete the specification of the consumer's view of the product.

The producer has a slightly wider definition of the product. He associates one more marketing aspect with the product than does the consumer. This additional aspect is the competitive strategy to be employed in marketing.
the product. The manufacturer is interested in how competitors will react to his marketing effort. If there is not currently any competition, he will be concerned with their time of entrance and how he may affect it. If competition already exists, the firm must establish levels for the elements of the marketing mix with the realization that competitors will react to these actions. There will be no reactions by competitors if there are a very large number of firms offering a homogeneous product. This would be a purely competitive market and in this case the market dictates the price and the producer can only vary the quantity to be produced. In markets where there are a few rival firms, an oligopoly, the quantities sold by a firm are dependent on the marketing mix of the firm and of other firms in the industry. Economists have proposed the concept of a kinked demand curve to help explain the oligopoly situation. See figure 1.

![Graph of Oligopoly Demand Curve]

Figure 1. Oligopoly Demand Curve

It is hypothesized that a kink exists at the current industry price ($P_I$). This kink will exist if other firms in the industry follow price decreases so the firm initiating the price cut will not gain the sales he would have expected. Conversely if the firm raises its price others may not follow and he will lose more sales than he anticipated. This concept of a kinked
demand curve can be extended to the marketing mix elements, but the number of dimensions would exceed three and one would have to imagine an "n" dimensional polyhedron to form a graphical picture. It is important to realize that the interdependence between the firms in the industry is generated by the adaptive rules employed by competitors. The kink is produced because competitors follow price decreases but not price increases.

The firm can choose from a number of competitive strategies. It could follow the marketing mix of the "leader" of the industry. Alternately, it could follow only the price level and not the promotion, distribution, or quality levels established by other firms in the industry. The firm has other strategy choices. It might not choose to react to the marketing mix elements of other firms, but rather adjust its marketing effort or parts of it on the basis of changes in its own market share or profit level. The firm might select a non-adaptive strategy and act as if it were independent of other firms in the industry. The selection of the best strategy depends upon how other firms in the industry will react to market changes. If the firm knew the strategies of the other firms in the industry it could choose the best counter strategy. This is not usually the case. The environment is usually a stochastic one in which only probabilities can be associated with the potential responses of competitors.

One method of approaching the stochastic nature of the competitive environment is to utilize Markov chains.\(^1\) The transition matrix could be used to describe the movement from one competitive situation (CS\(_i\)) to another as the result of a specific product strategy (k). If this form is to be used

each strategy would have a separate reward and transition matrix associated with it. The typical transition and reward matrix would be as follows:

**Transition Matrix:**

<table>
<thead>
<tr>
<th>Period $t$</th>
<th>Period $t+1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$CS_1$</td>
<td>$CS_{i1}$</td>
</tr>
<tr>
<td></td>
<td>$CS_{i}$</td>
</tr>
<tr>
<td></td>
<td>$CS_{i}$</td>
</tr>
<tr>
<td></td>
<td>$CS_m$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$CS_1$</th>
<th>$CS_{i}$</th>
<th>$CS_m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_{11}$</td>
<td>$p_{i1}$</td>
<td>$p_{mi}$</td>
</tr>
<tr>
<td>$p_{1}$</td>
<td>$p_{i}$</td>
<td>$p_{m}$</td>
</tr>
</tbody>
</table>

$CS_i =$ competitive situation

$P_{km} =$ Probability of moving from competitive situation $m$ to $i$ in period $t$ to $l$, by using strategy $k$.

$r_{mi} =$ reward firm receives in moving from competitive situation $m$ to $i$ in period $t$ to $t+1$, using strategy $k$.

**Reward Matrix:**

<table>
<thead>
<tr>
<th>Period $t$</th>
<th>Period $t+1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$CS_1$</td>
<td>$CS_{i1}$</td>
</tr>
<tr>
<td></td>
<td>$CS_{i}$</td>
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<tr>
<td></td>
<td>$CS_{i}$</td>
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<tr>
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<td>$CS_m$</td>
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</tbody>
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<table>
<thead>
<tr>
<th>$CS_1$</th>
<th>$CS_{i}$</th>
<th>$CS_m$</th>
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</thead>
<tbody>
<tr>
<td>$r_{11}$</td>
<td>$r_{i1}$</td>
<td>$r_{mi}$</td>
</tr>
<tr>
<td>$r_{1}$</td>
<td>$r_{i}$</td>
<td>$r_{m}$</td>
</tr>
</tbody>
</table>

The strategies $(k)$ could be the set of alternate adaptive rules the firm would consider using. The competitive situation $(CS_i)$ might be visualized as the market share or some other measure of relative standing in the industry. Assuming that the firm is able to carry out the product strategy $(k)$, the rewards occurring to the Markov chain for each strategy could be calculated and compared over given planning periods. The strategy with the greatest rewards would be selected. This approach considers the stochastic nature of competitive environments, but it does not explicitly consider the mutual dependence between the effects of competitive decisions by all firms in the industry. The mutual dependence aspects of the competitive problem have
been presented by Shakun in a previous reading.\(^2\) This game theory approach has been extended to the total marketing mix by Philip Kotler.\(^3\) In Kotler's formulation the competitive effects are reflected in the market share:

\[
MS_{i1} = \frac{EP \cdot EA \cdot ED}{n \cdot \sum_{i=1}^{n} P_{i1}A_{i1}D_{i1}}
\]

\(MS_{i1}\) = market share for firm one and product \(i\)

\(P_{i1}\) = price of product \(i\) and firm \(i\)

\(A_{i1}\) = advertising for product \(i\) and firm \(i\)

\(D_{i1}\) = distribution effort for product \(i\) and firm \(i\)

\(EP\) = price elasticity

\(EA\) = advertising elasticity

\(ED\) = distribution elasticity

\(n\) = number of firms in industry

This expression reflects the relative effectiveness of the firm's marketing mix when compared to the industry. This competitive term could be placed in a total demand equation so that the profit implications of the firm's and competitors' strategy could be determined.

When the profit to the firm is generated for each combination of strategies and counter-strategies, a reward matrix can be tabulated. This matrix can be analyzed by game theory. The firm may wish to protect itself

\(^2\)See readings in the advertising chapter.

\(^3\)Philip Kotler, "Competitive Strategies for New Product Marketing Over the Life Cycle,"\ Management Science, vol. 12, no. 4(December, 1965), pp. 104-119 (also reprinted at the conclusion of this chapter).
and choose the strategy that generates the most reward, assuming the competitor makes his best decision response. This is the maximin solution of the game. The manager could use other decision rules to select a strategy. He could be an optimist and select the strategy which has the chance of yielding the greatest reward, the maximax solution. A linear combination of these solutions would yield the Hurwitz optimism-pessimism solution. Other criteria such as minimax regret might be used. These criteria reflect an environment of uncertainty where there is no knowledge of the possible actions the competitor might take. If the manager can ascribe probabilities to each of the potential strategies of the competitor, a risk situation would exist and the best strategy choice would be the one that generates the greatest expected value of profit.

There are some problems with the game theory approach. First, solutions for the selection criteria are easily found only if a duopoly exists or if all other competitors can be considered as one opponent. If there are more than two parties to the game the solution is difficult to specify. Even with two players, a stable equilibrium strategy pair of pure strategies may not be present. The non-equilibrium situation would result in a change of strategies after each time period. Another problem with the game theory format is that the total rewards of the game are generally assumed to be fixed. This may

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4 See Appendix for a discussion of the elementary features of game theory.

5 A mixed strategy equilibrium will exist for a two person game with a fixed total reward, but the relevance of mixed strategies in the context presented here is difficult to accept. It implies using one adaptive rule some of the time and another the remainder of the time.
not be true. The non-zero sum nature of the game may arise since some combinations of strategies may generate more total profit for the industry than others. If the game is not zero sum an equilibrium solution probably will not be generated. Both of these criticisms discount the possibility of finding an equilibrium solution, but even if an equilibrium is not generated the game theory approach appears to be the best way to comprehend the competitive interdependence that exists in oligopoly industries.

With these underlying marketing mix and competitive characteristics of the product in mind, specific product planning problems can be outlined. In this chapter product planning problems are divided into two classes: new product decisions and product line decisions. New product decisions relate to adding new products to the firm's offering while product line decisions relate to dropping or changing existing products in the firm's multi-product offering.

**New Product Decisions**

The role of new products in the continuing growth and profitability of the modern corporation has become widely recognized. Firms find that new products may offer competitive advantages and generate additional profits. The modern firm attempts to produce a stream of successful new products that will enable it to obtain a healthy and profitable growth rate.

The selection of new products for introduction to the market is a very difficult decision. It is estimated that fifty percent of the new products that are introduced on the market are not a financial success. This failure rate reflects the complexities and difficulties associated with new product decisions.

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The new product decision can be viewed as a four step process: generating new ideas, screening these ideas, analyzing resulting proposals, and implementing acceptable products. See figure 2.

**Figure 2. Product Planning System**

This process begins with a search procedure designed to generate a large number of new product ideas. These ideas are then screened to remove those suggestions that are not compatible with the goals of the firm or are obviously unsuitable. The new product proposals that pass through the screening step are then analyzed. This analysis takes place in an information network. At each step in the process the product can be adopted (GO decision), rejected (NO decision), or investigated further (ON decision). If an ON decision is reached the evaluation analysis is repeated and the sequence continues until either a GO or NO exit is made. If a GO decision is reached the firm has committed itself to the product and implementation of the new product marketing plan is begun.

The implementation step may include additional efforts in the area of product development or market testing before full commercialization, but a GO decision represents a commitment which will not be reversed unless the underlying parameters of the analysis change.
Generation of New Product Ideas

In the first step of planning process attempts are made to generate a large number of new product ideas. These ideas may come from internal sources such as the salesmen, research and development personnel, and past company records, or they may come from external sources such as customers, competitors, industry associations, and industry research groups. The company would like to generate a meaningful set of potential new product ideas. To accomplish this it may budget an amount of funds to search for new product proposals. This sum must then be allocated between the search areas. This is a problem of maximizing the number of relevant new ideas subject to a search budget constraint.

\[
\text{(2) Maximize: } \text{NPI} = \sum_i S_i X_i \\
\text{Subject to: } \sum_i X_i \leq \text{SB} \\
X_i \geq 0
\]

NPI = new product ideas

\( S_i \) = search potential of area \( i \) expressed as the potential number of relevant new ideas generated per dollar of search expended

\( X_i \) = number of dollars spent on search in area \( i \)

\( i \) = index of areas to search. For example:

\( i = 1 \) may be surveying customers on future needs
\( i = 2 \) may be monitoring of competitor's new products
\( i = 3 \) may be a search of the firm's past and present research and development efforts
\( i = 4 \) may be a survey of the company's salesmen
\( i = 5 \) may be a search of existing patents
\( i = 6 \) may be setting a brainstorming committee of the firm's managers
\( i = 7 \) other sources of new product ideas

SB = search budget

The values of the $S_1$'s will probably not be constant with respect to $X_1$, so the problem would be a non-linear programming problem. Piece wise linear programming routines could be used since each $S_1X_1$ term could be broken into a series of $S_1X_1$ linear segments.\(^8\)

It is interesting to examine changes in the level of the budget constraint. The determination of the search budget level is based on an estimate of the amount of search needed to produce an attractive set of new product ideas. Changes in the budget are made by balancing the costs required to generate additional new ideas versus the possibility of discovering a highly desirable new product idea that had previously not been located. If a sufficient set of proposals were identified, additional resources would be better spent in evaluating the existing proposals rather than searching for new ideas. The determination of an optimal search policy is needed. This policy would be optimal when the increase in the value of the set of ideas due to locating new proposals equals the cost of search.\(^9\)

The output of the generation step is a listing of potentially desirable new product ideas. These reflect the identification of market needs and technological developments the firm may find profitable to exploit.

**Screening**

After a set of potential projects have been identified the next step in the analysis is to screen out the obviously unsuitable ideas. This screening

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\(^8\) See appendix on math programming. Lagrangelan analysis would be appropriate if the set of partial equations could be solved.

\(^9\) The determination of the "value" of the set is troublesome. One approach is the expected value of the profit generated by the products accepted. See James B. MacQueen, "Optimal Policies for a Class of Search and Evaluation Problems," Management Science (July, 1964), pp. 746-60, for an approach to this problem.
is intended to identify those ideas which are not compatible with the company's goals, do not match the company's capabilities, or do not appear to have enough market potential.

The first two criteria are elimination criteria for the idea. If the company has decided to restrict itself to durable consumer products, all non-durable consumer products would be removed from the set of ideas because of incompatability with the goal structure even though they might show great profit potential. The next elimination factor reflects the technical, financial, and managerial capabilities of the firm. If the firm cannot produce the product or does not have the technical or managerial abilities necessary for the product, the idea would be rejected.

After the products have passed through these rough elimination screens, the remaining ideas are ranked to determine the least suitable ideas. This ranking reflects a rough consideration of all the relevant factors associated with the proposed idea.

The basic factors relating to the decision are listed in Figure 3. The over-all considerations relate to the profit to be generated by the new product, the investment required to obtain this profit, the risk associated with the proposed product, and the interaction effects the new product will have upon existing product offerings.

The profit generated by the new product will depend upon both the demand and cost associated with the product. The demand for the new product will probably change over time; the product will grow, reach maturity, and decline over its life cycle. The quantity sold in any one year will not only depend upon the stage of the life cycle, but will also depend upon the price level, the amount of advertising expenditure, the equality level, and the intensity of the distribution and sales effort in each year. These factors
PROFIT -------------- DEMAND -- LIFE CYCLE, PRICE, ADVERTISING, DISTRIBUTION, COMPETITION, QUALITY
COST ---- PLANT SIZE, TECHNICAL POSSIBILITIES, UTILIZATION OF THE PLANT, FUTURE TECHNICAL DEVELOPMENTS
TIMING OF PROFITS

INVESTMENT--------- AMOUNT OF INVESTMENT REQUIRED
TIMING OF OUTFLOW

RISK---------------- AMOUNT OF RISK DECISION MAKER WILL ASSUME, RISK IN MARKET, AND UNCERTAINTIES OF ESTIMATION

CONSTRAINTS-------- MANAGEMENT LIMITATIONS
PLANT CAPACITY
FINANCIAL LIMITATIONS
DISTRIBUTION REQUIREMENTS
GOVERNMENT REGULATIONS
LABOR RESTRICTIONS

INTERACTIONS ------ EFFECTS NEW PRODUCT WILL HAVE ON EXISTING PRODUCTS NOW OFFERED BY THE FIRM

Figure 3. Factors Affecting the New Product Proposal
together constitute the marketing mix for the new product. The sales of the product will depend upon not only the level of each factor in the mix, but also upon their combined effectiveness. The competitive environment, as well as the marketing mix, surrounding the new product will affect the firm's sales of the product. The competitive effects will depend upon the competition's strategies and the counter-strategy employed by the introductory firm. The total sales of the firm will depend upon the resultant effects of the competitive and marketing mix factors.

The costs of production will depend on the plant size, the technological level of plant facilities, and utilization of the plant. The new product decision will also be affected by future technological developments. A firm may be less likely to invest in a large productive plant if developments in the future may significantly lower production costs. If this happens the competition could enter at these lower costs and force the originating firm to an unprofitable price level.

The combination of the demand and costs will determine profits for the new product. These profits will be received in future years, so the timing of this cash inflow will affect the return on investment and the time value of the inflow should be considered.

The investment required for the product will be an important parameter in the decision. The amount and timing of the investment outflow must be combined with profit considerations to see if the return on investment is satisfactory. The determination of the satisfactory level of return will not only depend upon the level of profits and investment, but also upon the amount of uncertainty the decision maker will assume. The total uncertainty will depend upon the risks inherent in the market and the uncertainties of estimation. This uncertainty will be balanced against profit. Since profit will depend upon the
price, advertising, and distribution level the firm designates, as well as the
cost structure it establishes, the decision concerning the product should be
made at the point where the optimum marketing mix and cost structure are
established. Here profits are greatest.

In striving for this maximum profit level for the new product, certain
constraints will have to be met. The level of the constraints may affect the
desirability of proceeding with the project. The production facilities open to
the new product may be limited, the availability of trained managers may be
restricted, the financial budget for the new product may be constrained, the
size of the sales force or distribution system may be fixed, or government and
labor restrictions may be significant. The existence and level of these constraints
will affect the demand creation, investment, and cost aspects of the new
product proposal.

The new product will probably not be offered as an entity independent of
the other products currently being sold by the firm. The new product may
reduce or increase the sales of other existing products offered by the firm.
In addition to these demand interactions, cost interactions may be felt. The
proposed product may change the unit production and marketing costs of other
products. The new product will certainly affect old products if common resources
such as advertising funds are allocated between them. The new product may also
affect the total risk associated in the firm's line of goods. Its sales fluctuations
may amplify or compensate for variations in other products. These interactions
may be important to the advisability of adding the new product.

Combining these factors at the screening stage could be done by
a subjective evaluation of how well each factor requirement is met. A panel
of top managers might be asked to rank each factor on a five point scale
from unsatisfactory fulfillment to excellent fulfillment of factor
requirements. A series of questions would be asked and an over-all ranking would be made. For example, a rough evaluation on the factor of product line interdependence might be approached by a subjective ranking at the screening stage. The question may be expressed as follows:

How will this proposed product fit with our product line?

<table>
<thead>
<tr>
<th>Very Incompatible</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Very Compatible</th>
</tr>
</thead>
</table>

Similar rankings could be made for each important factor. Preliminary calculations and rates of return on investment help establish the scores for the factors of investment and profit. After each factor has been ranked they must be combined to produce one over-all ranking. This is most simply done by weighting each factor and calculating the weighted average score.

\[
\text{SCORE} = \frac{\sum_{j=1}^{f} W_j F_j}{\sum_{j=1}^{f} W_j}
\]

\(F_j\) = factor numerical score (e.g. scale of one to five)
\(W_j\) = weight associated with factor \(j\)
\(f\) = number of factors to be considered

If more than one person has ranked each factor, the factor score \((F_j)\) could be determined by an average of each member's score for that factor. An alternate averaging procedure would be to weight each member's score by the confidence he has in that score.

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The confidence respondent has in his ranking (e.g. reciprocal of 90 percent confidence range on $F_{jk}$)

$$ F_j = \frac{\sum_{k=1}^{r} C_{ik} F_{jk}}{\sum_{k=1}^{r} C_{ik}} $$

$r = \text{number of respondents}$

The final rankings produce scores that serve to establish a rough index of the relative desirability of each project. By establishing a lower cutoff value, the apparently unsuitable projects can be eliminated. The remaining set of projects then passes on to the analysis stage for detailed profitability analysis.

**Analysis**

At the analysis node the projects that have passed through the screening network are subjected to a detailed evaluation. After this evaluation three alternatives are present: the project may be rejected (NO decision), the project may be accepted (GO decision), or more information may be sought concerning the project (ON decision). The analysis step in the new product decision process can be visualized as a networking problem. See figure 4 for a network example. At each ON decision a number of studies could be carried out to lead to the next evaluation.

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11 This networking approach was first presented by A. Charnes, W. W. Cooper, J. K. DeVoe, and D. B. Learner, DEMON: Decision Mapping Via Optimum GO-NO Networks -- A Model for Marketing New Products (a report presented at the Tenth International Meeting of the Institute of Management Science, Tokyo, Japan, August 24, 1963), p. 3 (also reprinted at the conclusion of this chapter).
With this formulation in mind the analysis decision can be visualized as a two stage maximization. The first stage is an optimization of the controllable parameters associated with the project at the present evaluation node. This optimization might be to maximize the profit associated with the product subject to the financial, managerial, and technical constraints on the problem. After this optimum state of the project has been defined at the evaluation node, the GO, ON, or NO decision is made. If an ON decision is made the second stage maximization is undertaken. This maximization is a determination of the optimum route to follow through the remaining nodes of the information network. It is designed to define the optimum sequence of studies to be carried out to reach a GO or NO decision. Both of these maximizations may be repeated at each evaluation node. The ultimate output of the analysis is a GO or NO decision for the product. If a NO decision is reached, the project is rejected. If a GO decision is reached the optimum marketing mix and production variables are specified. Since the second stage optimization specifies the most efficient path to a terminal GO or NO decision, the final decision is reached in such a way that the long run return on the research finds is maximized.

**First Stage Maximization**

The first stage maximization is based on a mathematical integration of
the factors considered in the screening stage. The integration can be approached by defining mathematical demand, cost, allocation, and uncertainty models. This approach yields a decision by comparing the maximum profit specified by the demand, cost, and allocation models with uncertainty to yield a GO, ON, or NO decision. See figure 5.

![Diagram](image)

**Figure 5. First Stage Analysis Model**

The demand for the product in functional form can be expressed as:

\[
X_{11} = f(P_{11}, A_{11}, CD_{11}, PS_{11}, Q_{11}, K_1, Pd_{21}, ..., Pd_{n1})
\]

- \(X_{11}\) = quantity of product one sold by firm one
- \(P_{11}\) = price of product one by firm one
- \(A_{11}\) = advertising for product one by firm one
- \(CD_{11}\) = channels of distribution for product one by firm one
- \(PS_{11}\) = personal selling effort for product one
- \(Q_{11}\) = quality level of product one by firm one
\[ K_1 = \text{competitive conditions in product one's market} \]
\[ P_{d1} = \text{demand characteristics for product 1 offered by firm 1 and other firms} \]
\[ n = \text{number of products offered by firm one affecting demand for product one} \]

To make this equation explicit the functional mathematical relationships must be specified. Several approaches can be taken to this problem. One method is to use "performance rations." In this case the demand is assumed proportional to each variable by a factor called its "performance ratio." This linearization of the demand function is a very special case. The relationships can be made non-linear by using factors of the form \( Y_1^{E_Y} \), where \( E_Y = \frac{dX/X}{dY/Y} = \text{the elasticity of demand relative to } Y \). In this formulation \( E_Y \) must be constant so the effect of each variable must be one of a number of specific forms. See figure 6.

12 David B. Learner, "DEMON New Product Planning: A Case History," in New Directions in Marketing, ed. Frederick E. Webster, Jr. (Chicago: American Marketing Association, 1965) (also reprinted at the conclusion of this chapter).

\[ X = \text{quantity sold} \]
\[ E_Y > 0 \]
\[ E_Y = +1 \]
\[ 0 < E_Y < +1 \]
\[ E_Y = 0 \]
\[ E_Y < 0 \]

\[ Y = \text{independent parameter} \]
\[ E_Y = \text{elasticity} = \frac{dX/X}{dY/Y} \]

Figure 6. Constant Elasticity Curves
If these forms are appropriate and assuming each parameter to be an independent variable, the industry demand equation in year t can be written as:

\[ X_{1t} = aX P_{1t}^{EPI} A_{1t}^{EAI} CD_{1t}^{E(CD)I} PS_{1t}^{E(PS)I} Q_{1t}^{E(0)I} \]

where "a" is a scale constant.

- EPI = industry price elasticity
- EAI = industry advertising elasticity
- E(CD)I = industry distribution elasticity
- E(PS)I = industry personal selling elasticity
- EQI = industry quality elasticity

\( \bar{X}_t \) is added to the equation to reflect the expected growth of the new product. It reflects the predicted sales of product X at year t in its life cycle for a given marketing effort. The actual sales \( (X_{1t}) \) in year t will be different from \( \bar{X}_t \) if the parameter values (e.g. P, A, CD, PS, Q) are not the ones originally used to estimate the life cycle sales levels.

General non-linear or discontinuous functions can be admitted by expressing each \( Y_1^{EY} \) as a response function which measures the proportionate change in the quantity sold (i.e. \( X/\bar{X}_t \)) as a result of an absolute change in the level of \( Y_1 \). The partial demand relationship shown by equation (6) represents the industry demand of the new product (note the specified elasticities are industry elasticities). To represent the demand for the firm, the industry equation must be multiplied by the competitive expression (in this case equation 1) and then multiplied by a product interaction term. The interaction term could

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13 Kotler, op. cit. presents an alternate formulation

be of the form:

\[
\text{INTERACTION} = P_2 \text{CEP12}_2 \text{CEA12}_2 \text{CED12}_2 \text{CPS12}_2 \text{C012}_2 \ldots
\]

\[
P_n \text{CEPln}_n \text{CEAn}_n \text{CPSln}_n \text{C0ln}_n
\]

The subscripts on the variables refer to other products offered by firms.
The exponents are cross elasticities with respect to the indicated parameters.
The cross elasticities measure the proportional changes in the sales of product one as a result of a proportional change in the level of a parameter of another product offered by the firm. For example, the cross personal selling elasticity between 'one' and 'j' is:

\[
\text{CPS}_{1j} = \frac{\partial X_1}{\partial P_{S_j}}
\]

\[
X_1 = \text{sales of product one}
\]

\[
\partial X_1 = \text{partial differential of } X_1
\]

\[
P_{S_j} = \text{level of personal selling for product } j
\]

\[
\partial P_{S_j} = \text{partial differential of } P_{S_j}
\]

With the realization that each \(Y_{j}^{CEY1j}\) term could be a cross response function that measures the proportional change in \(X_1\) as the result of an absolute change in the value of a parameter of another product, a general demand equation can be formulated. The complete equation would be:

\[
X_{1lt} = a_{lt} P_{lt} A_{lt} C_{Dlt} C_{PStlt} C_{0lt}
\]

\[
\sum_{j=2}^{n} \text{CEP}_{lj} \text{CEA}_{lj} E(CD)_{lj} E(PS)_{lj} E(O)_{lj}
\]

\[
P_{lt} A_{ilt} C_{Dlt} C_{PStlt} C_{0lt}
\]

\[
E_{pl} E_{EA} E(CD)_{E(PS) E(O)}
\]

\[
X_{1lt} = \text{quantity of product one sold by firm one in year } t
\]

\[
a = \text{scale constant}
\]

\[
\bar{X}_t = \text{life cycle estimate for year } t
\]

\[
P_{lt} = \text{industry price for product one in year } t
\]

\[
P_{St} = \text{industry selling effort for product one in year } t
\]
\[ Q_{it} = \text{industry quality for product one in year } t \]
\[ A_{it} = \text{industry advertising for product one in year } t \]
\[ C_{dt} = \text{industry distribution for product one in year } t \]
\[ E_{YJ} = \text{industry elasticity for parameter } Y \]
\[ P_{ijt} = \text{price for product } j \text{ by firm } i \text{ in year } t \]
\[ A_{ijt} = \text{advertising for product } j \text{ by firm } i \text{ in year } t \]
\[ C_{ijt} = \text{distribution for product } j \text{ by firm } i \text{ in year } t \]
\[ P_{Sijt} = \text{personal selling for product } j \text{ by firm } i \text{ in year } t \]
\[ Q_{ijt} = \text{quality for product } j \text{ by firm } i \text{ in year } t \]
\[ \text{EX} = \text{firm } i \text{'s elasticity with respect to } X \]
\[ \text{CEXij} = \text{cross elasticity between products } 1 \text{ and } j \text{ with respect to parameter } X \]
\[ n \]
\[ \Pi = \text{product sum over } j=2 \text{ to } n, \text{ where } n \text{ equals last product interdependent } j=2 \text{ with product } 1 \]

The cost function associated with the new product is most simply represented by a function:

\[
(10) \quad TC_{ijt} = FC_{ijt} + (AVC)_{ijt} \cdot X_{ijt}
\]

\[ TC_{ijt} = \text{total cost for product one in year } t \]
\[ FC_{ijt} = \text{fixed cost for product one in year } t \]
\[ AVC_{ijt} = \text{average variable cost for product one in year } t \]
\[ X_{ijt} = \text{quantity of product one produced in year } t \]

If in this equation \( AVC = \text{constant} \), there are no changes in the variable unit cost of the product as quantities are changed. If \( AVC \) is a function of the quantity of the good produced, a single non-linear equation could describe the costs. If the product has costs interdependencies with other products, the cost function would be more complex. These interdependencies might arise because the products share the same production resources or compete in the same input factor markets. It would be possible to use the elasticity or response function
form to comprehend the dependencies. The constant elasticity form would be:

\[ T_{C1t} = FC_{1t} + AVC_{1t}(X_{1t}) X_{2t} X_{3t} \ldots X_{jt} \ldots X_{nt} \]  

(11) \[ CC_{12} CC_{13} CC_{lj} CC_{ln} \]

\[ CC_{lj} \] is the cross cost elasticity between product one and \( j \).

\[ CC_{lj} = (\partial MC_1/\partial X_{1j})/(\partial X_{1j}/\partial X_{1}) \] where \( MC_1 \) = marginal cost for product one.

Given the demand and cost functions the total profit produced by the new product can be calculated, but this may not be the appropriate profit to credit to the new product. The new product may affect the profit of other products in the firm's offerings. The new product is actually responsible for only the change in the firm's total profits. This over-all change may be called the "differential profit." The differential profit in any year is the difference between the profit generated by the new line less the estimated profits of the line if the new product had not been introduced.

\[ DP_t = PROFIT_{NEW,t} - PROFIT_{OLD,t} \]

(12) \[ DP_t = \text{differential profit in year } t \]

\[ PROFIT_{NEW,t} = \text{total new line profit in year } t \]

\[ PROFIT_{OLD,t} = \text{estimated old line profit for year } t \]

The new line profit is the sum of the profit of the products in the line after adding the new product.

\[ PROFIT_{NEW,t} = \sum_{j=1}^{m} P_{jt} X_{jt} - \sum_{j=1}^{m} AVC_{lt} X_{lt} \]

(13) \[ m \]

where \( m = \text{number of products offered by the firm.} \)

When this is summed over a specified planning period (PP), and discounted at the firm's target rate of return on investment (RR), the discounted differential profit can be calculated.

\[ DDP = \sum_{t=1}^{PP} \frac{DP_t}{(1+RR)^t} \]

(14)
This differential profit function can be used as the objective function for the first stage maximization. The problem is to maximize the differential profit subject to the production, distribution, and financial constraints on the firm.

As equations (1) to (14) indicate, the discounted differential profit is a very complex function of many variables. It is dependent upon the demand and costs of each product in the line, which in turn are dependent upon the levels established for each of the variables in the marketing mix (P, A, CD, PS, Q) and the competitive environment. The function is further complicated since the levels of these variables may be changed in each time period and dynamic lagged effects may be produced. The first stage optimization attempts to locate the dynamic marketing program for the new product that produces the greatest discounted differential profit over a planning period while satisfying the financial, production, distribution, and managerial constraints in each time period.

This maximization is difficult because the nature of the profit function usually precludes the use of analytic solution procedures. The function is not linear and the number of variables is large. Calculus and non-linear programming may be applicable in some simple cases, but the problem must usually be solved by an iterative search routine. For these reasons most new product decision frameworks do not attempt to reach a maximum, but rather select the best of a number of trials specified on a "what if" basis or from a restricted set of alternative situations.

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15 See appendix for a review of search techniques and the applicability of non-linear programming routines.

The first stage maximization is a significant one since the initially proposed level of variables may be far from the optimum marketing program. During this first stage optimization, it is also valuable to examine the effects of changing the level of the constraints on the problem. The selection of better constraint levels may increase the profitability appreciably.

The result of the optimization is the maximum level of discounted differential profit and the optimal marketing program over the planning period. This return must now be balanced against the uncertainty and the investment associated with the project to reach a GO, ON, or NO decision. The decision would be relatively simple if the estimates of demand, cost, and interdependency were known with certainty. This is not usually the case in new product decisions. Great uncertainties exist about the product because by its nature it is new and very little previous experience has been accumulated that is directly relevant to the product.

The uncertainty associated with the project can be determined by estimating the over-all probabilities associated with levels of total profit other than the one predicted by the first stage maximization. This would generate a distribution about the best estimate of profit. The variance of this distribution would be a measure of uncertainty. Another approach would be to establish probability levels for deviations from each of the sub-factors in the problem. These estimates would generate distributions which would then be aggregated to product a total profit distribution.\(^{17}\)

In estimating the uncertainties, it is also important to realize that the product may not be independent of other products. Fluctuations in the new product might amplify or compensate for fluctuations in the sales and profits of existing products. A useful way of defining the uncertainty attributed to the

\(^{17}\)See Urban, op. cit., for details of the method of aggregation.
new product is by the concept of "differential uncertainty." The differential uncertainty is the change in the total uncertainty of the product line as the result of adding the new product. The output of the uncertainty estimation is an estimate of the distribution of differential profit levels about the best estimate produced in the first stage maximization.\textsuperscript{18}

The GO, ON, and NO decision must be made by balancing the return from the new product against the risk and uncertainty. The balancing of the risk and return may be achieved by dividing the return (ideally this would be differential profit) and uncertainty quadrant into three appropriate areas. This division could be accomplished by determining the firm's utility function relative to uncertainty and return. Constant utility lines would be sloped upward and to the right. By specifying the minimum level of utility for a GO decision and the maximum utility level to allow a NO decision, the risk and return coordinate for the proposed project could be plotted and a decision reached. See figure 7.

\[ U_3 > U_2 > U_1 \]
\[
\text{RETURN} = \text{expected discounted differential profit}
\]
\[ I = \text{investment outlay} \quad \text{D U} = \text{differential uncertainty} \]

Figure 7. Decision Quadrant

In this figure return is measured by the mean value of the discounted differential profit. The uncertainty is measured by the variance of the total differential profit distribution. The utility approach is troublesome to implement since the determination of the utility for a corporation is most difficult to determine.

\textsuperscript{18}See Urban's paper, \textit{op. cit.}, for the effects of changing uncertainties during optimization.
A simpler decision structure has been proposed in the DEMON model for new product decisions.\textsuperscript{19} This model divides the GO, ON, and NO areas on the basis of the probability of making a minimum payback and specified level of expected profit.\textsuperscript{20} The GO decision is specified when the expected value of profits is greater than a specified value and when the probability of a particular payback requirement is greater than the GO criteria level. The NO alternative is taken when the expected value of profit is less than a specified level or the probability of achieving a particular payback requirement is less than the NO criteria level. The remaining area is for the ON decision. The areas would appear as in figure eight if the total profit distribution was a log normal distribution.\textsuperscript{19}

If the profit and uncertainty coordinates of the proposed project fall in the NO area, it is rejected. If they fall in the GO area the firm makes a commitment to market the product and begins the implementation step of the new product process. If the project falls in the ON area the second stage optimization of the analysis is undertaken.


\textsuperscript{20} See Urban, \textit{op. cit.}, for a description of these criteria.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure8.png}
\caption{DEMON Decision Rules}
\end{figure}
In Figure 8, $I = \text{natural log of the required investment}$

- - - = line representing minimal probability of achieving payback goal for a GO decision

$\alpha_{GO}\)): ($\alpha_{GO} > 50\%$)

- - - = line representing maximum probability of achieving payback goal to allow a NO decision.

$\alpha_{NO}: (\alpha_{NO} < 50\%)$

_______ = line representing minimum expected value of profit for GO decision (EV$_{GO}$)

________ = line representing maximum expected value of profit allowing a NO decision (EV$_{NO}$)

Second Stage Optimization

After an ON decision is specified, the path leading to the next evaluation node must be chosen. The study to be selected should be optimal in terms of the total path to be followed through the information network. The path to be followed is determined by selecting the sequence of studies, the size of each study, and the total number of studies to be undertaken. The procedure is to select a path that appears to be the best one, given the data available at that ON node. After the first link is traversed, the GO, ON, or NO decision is again made. If an ON decision is specified, a new optimal path through the remainder of the information network is determined. Thus the project proceeds step by step down the information network, but each ON step is made by looking ahead through the network. This foresight at the ON node assures that the first ON study does not eliminate the possibilities of more advantageous use of that study link at other ON nodes. This is a heterogeneous sequential testing procedure. Each test is different and each test is selected by considering the optimum size, number, and sequence of tests to be carried out.

The first problem in the second stage optimization is the definition of
"optimum." One approach to this problem is to use Bayesian analysis. The optimal route through the network would then be the one with the greatest expected value of utility. For this analysis it will be assumed that the utility function is linear with respect to profit so maximum utility is equivalent to maximum profit.

![Diagram of possible sequences of three study links]

1 = market test  
2 = product cost study  
3 = study of potential competition  
S = stop by GO or NO decision

Figure 9  Possible Sequences of Three Study Links

The set of possible sequences is indicated in figure 9 when there are three studies available. After each study there is also the option to terminate the network. The expected value of profit would have to be calculated for each possible sequence. The expected value of profit for each sequence would be computed in the usual Bayesian decision tree fashion. Assuming: (1) $S_i$ states of nature and $P(S_i)$ prior probabilities for each state, (2) $Z_j$ possible results from the sequence of tests with associated reliabilities $P(Z_j|S_i)$ for the sequence, (3) a payoff matrix $R_{k_1}$ associated with the decision $A_1$(GO) and $A_2$(NO) and states of

21 See Wroe Alderson and Paul E. Green, Planning and Problem Solving in Marketing (Homewood, Illinois: Richard D. Irwin, 1964), pp. 216-237. For a Bayesian case study of this problem

nature \( S_i \), the expected value would be calculated for each possible sequence.

The expected value of the sequence \( \text{EV}_{S_0} \) is the expected value of the returns of the decisions that result from each \( Z_j \) less the costs of carrying out the sequence. The costs are the out of pocket costs of the study sequence and the opportunity costs that may be occasioned by competitive losses due to delay in introducing the product.

The value of the sequence:

\[
\text{EV}_{S_0} = \sum_{j} [P(Z_j) \cdot \text{EV}_j] - \text{COSTS} \\
P(Z_j) = \sum_{i} P(Z_j | S_i) \cdot P(S_i)
\]

where \( \text{EV}_j \) is the expected reward if \( Z_j \) occurs and the best decision is made. It is the greatest of

\[
\sum_{i} P(S_i | Z_j) \cdot R_{1i} \text{ and } P(S_i | Z_j) \cdot R_{2i}
\]

where

\[
P(S_i | Z_j) = \frac{P(Z_j | S_i) \cdot P(S_i)}{\sum_{i} P(Z_j | S_i) \cdot P(S_i)}
\]

See figure 10 for a typical \( \text{EV}_j \) branch. The sequence to be selected would be the one which has the highest expected value of profits.

![Figure 10. Typical \( \text{EV}_j \) Branch](image-url)
The computational burden of this Bayesian approach is large. Even with only four available studies, forty-nine sequences \([2(4 \cdot 3 \cdot 2 \cdot 1) + 1]\) would have to be evaluated. The number of studies is \(2 \times \text{permutation of } n \text{ studies} + 1\). This expands rapidly as the number and kinds of studies are increased and various sizes for each type of study are allowed. This computational burden could be reduced by an induction procedure similar to dynamic programming, but the computations would still be extensive.

Another approach to the second step optimization problem is by the use of matrix algebra to represent the networking problem.\(^{23}\) A network can be represented by a matrix of unitary coefficients and zeros. These are called \(x_{ij}\) where \(x_{ij} = 0\) or 1. "One" indicates selection of link \(ij\). A zero value for \(x_{ij}\) indicates that the link \(ij\) is not utilized. At the first node the alternatives are \(GO(x_{1G})\), \(ON(x_{1})\), and \(NO(x_{1N})\). One of these must be taken, so the sum of the first coefficients must equal one.

\[
x_{1G} + x_{1N} + x_{1} = 1
\]

If \(x_{1G} = 1\) then \(x_{1N}\) and \(x_{1} = 0\) since the sum of the \(x's\) are required to be equal to positive one. The second branch can be represented by removing the ON evaluation from the last step \((x_{1})\) and adding the study alternatives. With three alternatives, the branching requirement is:

\[
-x_{1} + x_{21} + x_{22} + x_{23} = 0
\]

where \(x_{2j}\) are the \(j\) tests available after the ON decision if step ON is reached. If \(x_{1} = 1\), this means one of the \(x_{2j}\)'s must be chosen. If \(x_{1} = 0,

\(^{23}\)A. Charnes, W. W. Cooper, J. K. DeVoe, and D. B. Learner, "DEMON: Decision Mapping Via Optimum GO-NO Networks - A Model for Marketing New Products," \textit{Management Science} (July, 1966) pp. 865-887. The following comments are based on this publication (also reprinted at the conclusion of this chapter).
all $x_{2j}$'s must be zero, which is the desired result if the network has been exited by a GO or NO decision at the previous stage. Continuing in this manner a set of equations describing the necessary conditions for movement through the links can be established as follows for three evaluation nodes:

$$\begin{align*}
(17) \quad x_{1G} + x_{1N} + x_1 &= 0 \\
-x_1 + x_{21} + x_{22} + x_{23} &= 0 \\
-x_{21} - x_{22} - x_{23} + x_{3G} + x_{3N} &= 0
\end{align*}$$

To find the best route through the network, reward values must be established for each route and a solution method applied to find the optimum route.

The DEMON model postulates an objective function of the form:

$$\begin{align*}
(18) \quad \text{MAX} & \left[ E(\rho \tau q(u,x_{ij}) - \sum_{i,j} C_{ij}(x_{ij})) \right] \\
\rho &= \text{unit profit rate} \\
\tau &= \text{number of the intervals in planning period} \\
q &= \text{random variable of rational demand - which depends upon the links transversed} (x_{ij}) \text{ and the mean of the demand distribution} (u) \\
C_{ij} &= \text{cost of transversing link} x_{ij}
\end{align*}$$

The functional relationship $q(u,x_{ij})$ must be specified before the second stage maximization can be undertaken. This function depends upon the information secured via the selected path. The authors of DEMON suggest that the information generated by transversal of a path might be represented by a linear estimate.\(^{24}\)

\(^{24}\)Ibid., p. 873.
\[ q = \sum \sum k_{ij} q_{ij} x_{ij} \]

\( k_{ij} \) = weight established for \( q_{ij} \)

\( q_{ij} \) = the combination of information gained by transversing link \( x \) and the previsions estimate \( q \).

\( x_{ij} \) = link transversed

This estimation relates the mean estimate of rational demand (\( u \)) to the path transversed. The specification of the form and values of the estimating function is the most difficult problem in the second stage optimization.

To optimize the DEMON objective function, recourse is made to linear algebra. The generalized inverse of the network conditions with certainty equivalents for the GO and NO reward functions can be theoretically used to locate the best information path.\(^{25}\)

The networking concepts and GO and NO conditions developed in the DEMON model were utilized in a revised formulation of the model called DEMON: Mark II.\(^{26}\) DEMON: Mark II builds on the theoretical base of the earlier model and attempts to develop numerical solution procedures for particular estimation and distribution functions. In the revised model chance constrained programming is proposed to solve the networking problem.\(^{27}\) The problem is formulated by defining the return at the evaluation node by a partitioned equation. If the demand is lognormally distributed (i.e. \( \ln(q) \) is normal),

---


\(^{27}\) See appendix for a discussion of chance constrained and stochastic programming.
(20) \[
\phi(X,q) = \begin{cases} 
E(\rho q) - C_0 + X & \text{if GO conditions are satisfied} \\
\max \sum \phi (X - C_j, q) f_j(q|q) d(q) & \text{if ON} \\
X & \text{if NO}
\end{cases}
\]

\( q = \) demand level as currently known

\( E(\epsilon q) = \) expected total profit for product

\( C_0 = \) cost of introducing product

\( X = \) amount of funds remaining of initially specified study budget

\( C_j = \) cost of study \( j \) [note: \( C_j \) could include the competitive costs of delay]

\( q = \) demand observed after study \( j \) is carried out

\( \phi(X-C_j,q) = \) reward function after study \( j \)

\( f_j(q|q) = \) conditional distribution of observing \( q \) given the existing observation

\( dq = \) differential with respect to \( q \)

The ON equation depends upon the remainder of the information network. The ON equation is fully represented only after writing an additional partitioned equation for each of the succeeding nodes. These equations become very complex when the number of nodes is greater than two. The complexity is increased when it is realized that the available set of alternatives at succeeding ON nodes may be different from previous ones. After the additional equations have been formulated they must be combined into one over-all equation so that chance constrained programming can be implemented. This combination can be obtained after positing a special solution form for the equation set.  

\[28\] Although A. Charnes, W. W. Cooper, J. K. DeVoe, and D. B. Learner, DEMON: Mark II Extremal Equations Solution and Approximations, Northwestern University, 1965 (Systems Research Memo No. 122, Technological Institute),
the equations can be reduced to a single equation system, the compounding complexity produced by the number of nodes and choices of studies makes the DEMON: Mark II model computationally feasible for only very simple networks (less than three ON nodes). 29

Although attractive theoretical formulations for carrying out the network optimization have been proposed, computationally feasible models do not exist to carry out the second stage optimization. This inability to specify the complete network may not be too significant since an evaluation will be conducted after each study in any event. The analysis may proceed in a stepwise fashion down the network, but without the second stage optimization it does so only in a myopic way. It sees only the next study rather than considering the best total information network available at that point in time.

New Product Selection At the Analysis Stage

The two step maximization approach presented above must be modified in some respects when the problem is not one of evaluating a new product proposal, but rather selecting from a group of new product proposals. This new problem is further complicated by the fact that each project may be at different nodes in the information network. Some projects may have more information and less uncertainty associated with them than others. The ease of gaining additional information might also vary with each project. The project selection problem could be approached by using an information evaluation scheme to bring all of the projects to their best informational position. The second stage optimization approaches indicated in the last section can serve this purpose, since they

29 Ibid, p. 18.
give an estimate of the optimum level of information and profit for a project facing the remainder of its information network. With this new estimate for the return and uncertainty associated with the project, the addition of combinations of the new product ideas could be proposed and tested by the procedures developed in the single product first stage optimization. The computational burden of this testing could be large if the new products are interdependent with themselves, as well as existing products. The number of trials necessary would be

\[ \sum_{i=1}^{n} C_i^n \]

where \( C_i^n \) = the number of combinations of \( n \) items taken \( i \) at a time and \( n = \) number of projects to be evaluated. If interdependent, the optimum marketing program will depend on the combination of products added and the total first stage optimizing search routine would have to be run for each combination that satisfies the firm's technical, managerial, and financial constraints. The best combination would then proceed down the decision network. Each product would be subjected to a GO, ON, or NO decision and the group combination would be re-evaluated in light of new information if an ON decision was reached. The computational problems of project selection deserve a good deal of research effort.

**Inputs to Analysis Stage**

The input demands for the analysis models described in this chapter are great. The models have been developed on a theoretical level and not as much attention as is needed has been directed toward the questions surrounding the generation of input for them.

The required demand, cost, and information network inputs could be estimated on a subjective basis that reflects the decision maker's best judgement. This approach might be justified because the decision must be made and if the model is
not used, a much simpler and perhaps less accurate decision procedure would be used. Subjective inputs, however, should be used only after all empirical information relating to the problem has been considered.

The relationships between the demand and the controllable marketing variables might be approximated by statistical regressions of empirical data. For existing products a bank of data would exist and statistical regressions would be feasible. If a proposed new product is expected to behave in a way related to an existing product, light might be shed on its demand responses by a regression of the related data. If this is not the case, resort must be made to subjective inputs with their associated confidence intervals. The best estimates would be used to calculate return and the confidence intervals to determine the uncertainty. If historical data relevant to the product is available, the industry elasticities and cross elasticities could be estimated from a regression of industry sales on past industry price and non-price variables. The use of logarithms on the equation would make the regression linear and usual econometric procedures could be used to estimate the constants -- the elasticities and cross elasticities.  

A similar procedure could not be used to determine individual firm elasticities since logarithms of the market share term would not produce a linear equation. The competitive price and non-price elasticities could be estimated by a direct search routine to minimize the associated Chi Square statistic.  

\[30\] See Ronald E. Frank and William F. Massy, "Short Term Price and Dealing Effects in Selected Market Segments," *Journal of Marketing Research* II (May, 1965), pp. 171-85, and also reprinted at the end of the pricing chapter of this book, for an application of the technique to market data.

\[31\] See Donald G. Morrison, "Testing Brand Switching Models," *Journal of Marketing Research*, (November, 1966), pp. 401-10, for a discussion of this technique (also reprinted at the conclusion of the stochastic models chapter of this book).
The competitive input is completed with a formalization of the reaction functions of the competing firms. These forecasts of future competitive response might be obtained by examining the past competitive responses to price and non-price changes.

The cost cross elasticities could be approximated by examining the cost records of the firm for various quantity mixes or by formulating a linear programming model to minimize the cost of producing specified quantities of the firm's products. Successive runs of the cost minimization model and a regression procedure could yield estimates of the cost cross elasticities.

The examination of past data could be supplemented by directed studies to measure the perceived interrelationships between products. Such a procedure has been developed by Barnett and Stefflre.32

The information network input demands are especially difficult. It seems reasonable to estimate the outcomes of various studies between the existing ON node and the next evaluation node. This input would be in the form of the most likely results of the study and the distribution about this estimate. This would supply a basis for determining the conditional distribution of the new estimate given the past estimate. The difficulty is confronted when attempts are made to forecast the results of a number of future studies. This input is needed to find the optimum path through the information network at the second stage optimization of the new product analysis. The estimation of future conditional distribution requires estimates of second and more remote studies before earlier studies are carried out. These problems of higher degree estimation are an additional restriction on full optimization down the network, but they

do not preclude effective step by step transversal of the network based on determination of only the next best study.

The problems of generating meaningful input deserve additional research effort. This would be especially true in the area of generating procedures for subjective estimation. Subjective estimates reflecting good business judgement must be relied upon frequently in new product decisions since little past data exists that is relevant to the new product innovation.

Implementation

Exit from the analysis stage of the information network is made by either a GO or NO decision. If a NO decision is reached the product is rejected and the decision process is terminated for that product. If a GO decision is reached the implementation of the marketing for the product is begun.

The GO decision reflects the accumulation of enough information about the project to make a commitment of the firm's resources to the product. This does not imply, however, that the firm will blindly proceed with the final marketing of the product. The firm must be very careful to be sure that early estimates of the demand parameters are not incorrect and that the parameters underlying the decision do not change. An information system must be set up to ascertain if the relationships assumed or estimated in the model remain correct.

This sensing system may be implemented before the full scale introduction is begun. A test market study may be undertaken to monitor changes that are taking place in the market. If changes in the decision relationships are noted, the project may be recycled through the analysis stage to re-optimize the marketing program for the project and to assure that the GO decision remains appropriate. The test market study may indicate new functional forms or change the uncertainty associated with the current estimates.
During introduction the sensing system is especially critical. The system monitors the introduction of the product and predicts the ultimate sales results for the product on the basis of early performance data for the product. The prediction of the sensing system would be one based on a model of consumer behavior in the new product market. A simple model could be one based on the assumption of a specific growth curve for the product. Lewis Fourt and Joseph W. Woodlock have hypothesized a growth curve of the form:\textsuperscript{33}

\begin{equation}
X_t = L(1 - a^t)
\end{equation}

\begin{align*}
X_t &= \text{sales in period } t \\
L &= \text{limiting value of sales as } t \to \infty \\
a &= \text{constant, } 0 < a < 1
\end{align*}

This equation can be used to monitor test market behavior or market introduction. The early sales data and an estimate of the parameter "a" could be used to predict the limiting value of sales (L). If early tests do not indicate the limiting value will be as great as expected, the project should be re-examined and either modified or dropped.

More complex growth curves are possible. For example, if a Gompertz curve or "s" growth curve was hypothesized for the market, early data could be used to approximate its parameters:

\begin{equation}
X_t = A^B_t \quad \text{is a Gompertz relationship}
\end{equation}

\begin{align*}
X_t &= \text{sales in period } t \\
A, B &= \text{constants}
\end{align*}

On the basis of the early sales results, estimates of A and B can be obtained by plotting the sales levels for each period of an \( \ln \ln X - \text{time} \) graph. The equation is then linear (\( \ln \ln x = t \ln B + \ln \ln A \)) and graphical extrapolation or linear regression procedures could be utilized to generate estimates of A, B, and future sales levels. If future sales levels are not as expected, the project would be recycled to the evaluation stage of the decision process. The association of a model of sales growth and new product implementation should be apparent. The model integrates the preliminary data and uses it to predict the future performance for the product.

The models of consumer behavior discussed in chapter three of this book could also be utilized at the implementation stage of the new product decision. For example, the linear-learning model discussed by Haines could be used during implementation to estimate market response relationships and to predict asymptotic amount of demand. Markov models might also be useful for prediction, since if early data can be used to estimate the transition matrix and if stationarity is assumed, the sales levels for future periods can be predicted.

William F. Massy has developed an intricate stochastic consumer model for monitoring the introduction of a new product. This purchase incidence model is based on the use of the Poisson distribution to describe the frequency of purchase of a particular brand. The parameters of the distribution are controlled by another stochastic distribution so that the model will encompass the heterogeneity of differing consumer preferences. The population is further divided into several classes on the basis of the number of their past purchases.

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of the brand and the parameters of each group are allowed to be different. This characteristic allows the model to display learning. The time between purchases is also a stochastic process in the model.

The model predicts the number of brand purchases over time. It does not directly predict the amount purchased. To produce sales volume estimates from the brand choice predictions, the assumption is made that the size of purchase is independent of the decision to choose the brand. With this assumption and a distribution for the size of purchases, sales volume estimates are produced. The estimates can be made for sales volume of sub-units of the market or the total market. The model also may be used to predict the long run sales volume of the new product.

These sales estimates are important in assessing the probable success of the product and in understanding the new product adoption process. Models used to predict the results of implementation can and should utilize the literature in the behavioral sciences concerning the nature of the diffusion of innovation. These behavioral concepts can be applied to give a sound theoretical base to the quantitative model ultimately required in the implementation stage of the new product decision process.

The output of these sensing models is data pertaining to the early performance of the product, estimates of the response relationships underlying the product, and predictions concerning the final performance of the product. This data should be used in an adaptive control system to update the new product decision. In the new product case the decision model would be the analysis stage. Early performance data or specific test data could be used as inputs to


the analysis stage to produce an updated decision (GO, ON, NO) and a new optimum marketing program for the product.

If a NO decision is specified on the basis of the new information gained during implementation, an abort routine would be undertaken to remove the product from the market and minimize the losses for the project.

If the monitoring system confirms earlier estimates and does not indicate changes in the decision relationships, the actual physical introduction would proceed. The coordination, planning, and control of the physical introduction can be encompassed in the structure of PERT or critical path models. The models require explicit recognition of the interrelationships between the various steps of implementation. With this input they can be used to minimize the time, cost, or risk associated with placing the product on the market. They may also serve to help allocate the implementation resources to assure maintenance of the introduction schedule.

Summary

The implementation step complete the new product decision process. This process began by generating a large set of potential new product ideas. These ideas were then screened to remove the obviously unsuitable ideas and to produce a meaningful set of new project proposals. Each proposal was then analyzed in an information network by a two step maximization procedure. In the first stage an optimum marketing program was developed for the product, given the present level of information. This optimum program and its associated return were compared with the level of uncertainty associated with the project at the present evaluation node to reach a GO, ON, or NO decision for the project. The second stage optimization began if an ON decision was reached. In this

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38 See Wroe Alderson, Marketing and the Computer
optimization a best route through the network was specified. The project continued down the network until an exit was made by a GO or NO decision. The NO decision terminated consideration of the project. If a GO decision was reached, implementation of the product was begun. PERT and critical path models may be used to help plan and control the many activities of product introduction. During implementation models of consumer behavior were utilized to assure the firm that the decision inputs were correct and have not undergone changes. If changes were sensed, the project was recycled through the analysis stage to update the decision (GO, ON, or NO), and the optimum marketing program. Application of this decision procedure should help reduce the failure rate of new products, increase new product profits, and lead to a stream of useful new products that will assure healthy growth for the firm.

Product Line Decisions

After a new product has been fully introduced to the market, it becomes a part of the firm's product line. This group of products behaves as a profit generating team. They are usually interdependent. Each may be a demand complement or substitute for other products in the line. Cost interdependencies reflecting production economies or diseconomies of joint production may be present. All the products in the line are interrelated by the allocation of fixed financial and managerial resources. Risk interdependencies may appear because the fluctuation of the products can amplify or compensate for fluctuations in other products. The product line problem is to determine the number of products and the marketing mix for each product that will maximize the total profit for the firm.
The number of products offered by the firm can be varied by adding new products or by dropping existing products. The first method is the new product problem discussed in the last sections. The second can be approached by using the models developed in analyzing new products. The decision to drop a product must be based on the change in total line profit and the change in the total risk associated with the line. Thus comparison of the differential profit and differential uncertainty can be accomplished by the decision framework described in the analysis stage of the new product decision procedure. The decision to drop a product may also proceed through an information network until it is decided to retain or drop the product. The first stage optimization might suggest a change in the marketing program of the old product, a decision to keep the product, and an increase in differential profit.

The specification of the optimum product line width could be directly attacked if the demand function facing the firm could be linked to the number of products offered by the firm. Baumol and Isle have structured this approach for the retail market. In their model the demand for the retail firm is a function of the number of products offered \((N)\). The single variable calculus model could be applied to specify the optimum product line width \((N)\) if the equation is differentiable, the first differential equation is solvable, and the sufficiency condition can be satisfied. 39

A more complex approach has been developed by Bob Holden. 40 Holden divides

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products into groups with a transfer effect ("K" commodities), without transfer effects ("O" commodities), and fixed price commodities ("\" commodities). These product definitions are used to investigate the marginal effects of adding or dropping a product from the line. Holden approaches the product line problem by first assuming all the products with a transfer effect ("K" commodities) are included in the line. With this assumption first order calculus conditions are developed and products are added to the line on the basis of their contribution to profit (d[profit]) until the firm's financial or physical constraints are met.

Holden's marginal approach to the product line decision does not consider the problem of how many complementary or substitute products should be added. The interdependent nature of the product line decision should be considered in determining the products to be included in the product line.

The considerations of interdependency that surround the determination and specification of the optimum size of the product line are similar to those of the new product selection problem discussed earlier in this chapter. The optimum combination of the available products must be selected and the optimum marketing program for each must be found. The analysis procedure described for interdependent new products could be extended to solve this problem. The first stage maximization of differential profit would become a function of the variables of all the products and the output would be the best marketing mix for each product. To find the best number of products to offer, the maximization would be repeated for each combination of products available.

The computational problems of this approach are large. The number of variables at each search would be n times the number considered in the new
product case where \( n \) = number of products in the line. The number of combinations to test would also be large as \( n \) increases.\(^{41}\) There are some compensating factors to ease the computational burden of the product line problem. Some of the parameters may be fixed by the market structure and other parameters may be variable within only narrow ranges. In addition, the number of combinations to test could be reduced by dividing the line into interdependent groups and then treating each group as independent of the others by fixing separate fixed resource allocations for each one. Then the total profit would be the sum of the profit of the group and optimization would be carried out only on each smaller group. Another compensating factor in product line decisions is the availability of data. Existing products have amassed a backlog of experience that can be used to estimate response functions and the other inputs necessary for optimization. The existing products are usually at about the same information level so that the information discounting problem of new product selection is not present. Even with these compensating factors the computational burden of the product line solution procedures is large. In most cases simplifying assumptions will have to be made to make the determinations of the optimum product line width and product marketing program a practical reality.

**Summary**

This chapter has formulated, analyzed, and discussed the problems associated with product planning decisions. With the understanding that the term product would include the physical good as well as the associated marketing

\(^{41}\)See Donald B. Rice, "Product Line Selection and Discrete Optimizing," (Institute Paper No. 66, January, 1964), Institute for Quantitative Research in Economics and Management, Purdue University, for a case in point and computational procedure.
characteristics of price, advertising, personal selling, channels of distribution, quality, and competitive strategy, the new product decision was attacked. The new product problem was viewed through a four step process of (1) generating new ideas, (2) screening proposals, (3) analyzing the projects, (4) implementing the new product. The result of utilizing this process is the decision to accept or reject each proposed product and a specification of the optimum marketing program for each accepted product. If a new product is introduced, it becomes part of the firm's product line. The determination of the best set of parameters for each product in the line and the number of products to be in the line is the product line problem. The similarities between this problem and the new product selection problem were noted and the associated computational problems were outlined. In both new product and product line decisions a synthesis of all the marketing elements discussed in previous chapters was required for an effective marketing management decision.


