MARKETING MODELS FOR OPTIMIZING
PRODUCT QUALITY

by

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B.S., University of Maine
(1950)

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF
SCIENCE
at the
MASSACHUSETTS INSTITUTE OF
TECHNOLOGY
June, 1963

Signature of Author ........................................
School of Industrial Management, May 1, 1963

Certified by ...............................................
Faculty Advisor of the Thesis
Professor Philip Franklin  
Secretary of the Faculty  
Massachusetts Institute of Technology  
Cambridge 39, Massachusetts  

Dear Professor Franklin:

In accordance with the requirements for graduation, I herewith submit a thesis entitled "Marketing Models for Optimizing Product Quality."

Professor Little, Thesis Committee Chairman, was very generous with his time and provided invaluable assistance throughout the thesis project. Professor Pounds, Committee Member, made many worth-while suggestions. I am most appreciative of the help from these two faculty members.

Sincerely yours

Colby Hackett Chandler
ABSTRACT

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Colby Hackett Chandler

Submitted to the School of Industrial Management
on May 1, 1963
in Partial Fulfillment of the Requirements
for the degree of Master of Science

The objective of this study has been to design marketing models for describing the optimum product quality position of a company.

A company profit model has been constructed and from it the mathematical conditions for optimum quality under various pricing policies have been derived. The model takes as known the product demand as a function of price and quality.

Next, product demand functions for a specific, hypothetical product line were synthesized using a segmented market model. The market was subdivided into several customer groups where individual demand characteristics were assumed. These groups were then assembled into a total market for which the maximum profit position with respect to quality was determined.

A competitive model was then constructed by adding a hypothesis about the effect that customer choice among competitive products has on market share. The model was used to explore strategies of new product introduction both for a company with existing products and for a company entering the market.

Finally, some actual company data were used to test the concepts of the models for reasonableness. Data on sales and profits as related to quality changes, price changes and new product introduction were qualitatively compared with the behavior of the model.

Thesis Advisor: John D. C. Little
Title: Associate Professor of Industrial Management
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Chapter I

THE PROBLEM AND THE OBJECTIVE

A. THE PROBLEM

Industry today needs to know the effect product quality has on sales and profits. Obviously quality is not the only product characteristic management must know more about; the assertion is merely that it is an important characteristic. Without a doubt all top corporative officials have a "feel" for the relationship between quality and product success. But a "feel" is not enough. More companies are competing with similar products; customers can afford to pay for higher quality and are demanding it; and finally manufacturing costs are continually mounting. These factors make it urgent that a more quantitative knowledge of the relationship between product quality and success in the market place be obtained.

Quality in Relation to Price

It would be surprising if one found a simple relationship between quality and the success of a product. Price is a prime consideration in most purchases. Customers search for the "best buy" or the most in quality or quantity for the least price. Therefore, in speaking of the optimum quality for a given product we should mean optimum quality in relation to price. Marketing managers have been heard to say that
their salesmen can promote products on the basis of price more effectively than on the basis of quality. This suggests that the marketing appeal of quality is a secondary consideration or requirement of customers. In other words, after examining price and determining that he has the ability to buy, the customer examines quality to see if he wants to buy. Actually these two steps can take place simultaneously or in reverse order, but it is virtually certain that both steps occur however subtle they may be. Product attributes other than quality and price are also important to customers; however, for this study the discussion will be limited to these two attributes.

**Diminishing Returns for Quality**

As the quality of a product is increased the cost of manufacture will generally increase. Since most manufacturers try to maintain a uniform margin of percent profit, price will usually increase as quality increases. While it may be true that customers want the highest possible quality, they are not always willing to pay in proportion to what it costs. As product quality is increased, a point of diminishing returns due to fewer purchases at higher prices is eventually reached.

There are two general approaches to the problem of diminishing returns. First, the quality level can be

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1 The term "margin" will be used throughout this report to mean "incremental profit as a percent of selling price."
selected which is just at the point of diminishing returns or maximum net revenues. Second, additional product lines can be introduced with different quality levels and different prices. The proper choice between these two alternatives is dependent upon the customers. If there is a wide range of quality desired by customers willing to pay accordingly, the choice of multiple product lines may well be advantageous. If multiple product lines exist, the analysis to determine optimum quality may be simply to determine the quality level required to maximize net revenues for each line at its fixed price level.

Here again there is a suggestion that price is the first consideration and quality second. Once it is established that customers are willing to pay a range of prices for a range of quality the next step is to find out what prices will have favorable reception. After the acceptable price levels are known, the manufacturer can proceed to determine the quality level required at each price to maximize net revenues. This approach might fall under the slogan commonly referred to in sales organizations as "We sell the customer what he will buy, not what we can make." The above procedure assumes that margin can vary among products and among manufacturers.

Studies of competitive markets have suggested that it might be more correct to assume margins as generally equal among products and companies. Competitors are continually studying the market to find the high margin products so that they may enter. This continual market entry results in price
competition which lowers the margin to some equilibrium level acceptable to all manufacturers.

With equal margins, the above discussion on quality optimization for multiple lines does not hold. To keep margin constant, both price and quality must vary. In this situation the proper approach might be to estimate sales for various price-quality combinations entered into the competitive situation and select the best alternative. A model of this approach will be given in Chapter VI.

Measure of a Product's Effectiveness

Before proceeding with a method for optimizing the quality-price combination it is necessary to have a criterion. Several related criteria exist, such as maximum sales or gross revenue, maximum profits or net revenue, and maximum return on investment. Sales can be dismissed as a criterion readily if we undertake to vary margins; however, with constant margins it would be a meaningful measure. Return on investment is a useful tool in managing a company and a proper consideration in planning capital expenditures for introducing new products. In order to confine the scope of this study to reasonable limits, it was decided to consider the situation where investments would be nearly equal for all alternatives and examine the effects on profits or net revenues. A worthwhile extension of this work would be to examine the use of return on investment as the optimization criterion.

There are many other criteria not discussed such as
maximum dividends per stockholder's shares or return on equity. These were not considered since they offer little or no advantage over profits in this modeling approach which is based on a hypothetical construct of a general situation. In cases where these more specific criteria are important they can be determined from the results of a maximized profits situation. Thus, maximized profits has been chosen as a criterion to give simplicity and the ability to derive other financial measurements.

B. PREVIOUS WORK IN THE FIELD

Current Literature

Mathematical modeling is currently a popular subject in the marketing field. Little work of this type appears in marketing literature prior to 1960. One gets the distinct impression from scanning the literature that the marketing experts consider the use of mathematical methods in marketing as in its infancy with a bright but somewhat unpredictable future.

Only two books could be found directed explicitly toward this subject, Mathematical Models and Methods in Marketing, edited by Frank M. Bass and others, and Quantitative Techniques in Marketing Analysis by R. E. Frank, A. A. Kuehn and W. F. Massy. These, and a limited number of other books which discuss the subject are shown in the bibliography. One periodical, The Journal of Marketing, includes several creditable articles on mathematical marketing models in the 1961
and 1962 volumes. These also are listed in the bibliography.

Much of the literature is limited to discussing the merits of quantitative methods without demonstrating their use. An exception is Mathematical Models and Methods in Marketing which is a compilation of rigorous mathematical approaches to eighteen diverse marketing problems. Especially valuable parts of this book are the editorial commentaries and appendices to each article, where the material is analyzed critically from different points of view.

"Optimal Advertising and Optimal Quality" by Robert Dorfman and Peter Steiner, contained in the book by Bass, is the only work discovered in the literature which discusses the market modeling aspects of product quality. Dorfman and Steiner have taken a purely mathematical approach with little attempt to study or test the inferences derived from their model. Their work, however, is an important step in starting the exploration of the value of quality in product design.

Absence of Quality in Marketing Models

Why is the literature nearly devoid of studies in product quality with mathematical models? Perhaps it is a matter of emphasis; price and advertising are known to have strong marketing impact, whereas quality is less understood. There may be a belief that quality has a relatively unimportant effect on company profits as long as a product is good enough to gain general market acceptance. Another possibility is that people do not consider quality as a decision variable as
they do price and advertising. Finally the answer may simply be uncertainty as to the proper approach, considering the difficulty in making suitable quality measurements.

If any of these postulated answers applies, then there is hope, for adequate rebuttals exist. Customers have demonstrated their sensitivity to quality in many markets such as clothing, foods, automobiles, entertainment and many others. The wide range of product quality lines offered in these products is testimony to quality being a market decision variable. Many of the new product lines have carved out new markets; high fidelity brought new life to the record business; improved electric shavers caused rapid growth in a market that had existed for a number of years.

Considering that the subjective nature of quality in most consumer products makes quality difficult to measure, it is understandable that work with quality in marketing models has been avoided. Even here, however, the argument should not stand unchallenged. Crude as they may be, some quality measures do exist. Several consumer reports are issued regularly giving the results of objective, though meager, tests. Market research organizations are becoming increasingly proficient at measuring consumer preferences. Information of this kind, combined with the quality measurements companies make in their inspection and quality control departments, provide an initial source of quality data. One might even optimistically believe that serious efforts to use quality data in mathematical models could "feed-back" guides on how to provide better quality
Marketing Variables other than Quality

Mathematical models in marketing have covered a number of subjects including sales forecasting, advertising, promotion, purchasing, brand preference, selling expense, distribution, inventory control and planning. Of these subjects, advertising and promotion have received considerable study. Advertising and promotion may have marketing effects similar to product quality. Their impact on customers is difficult to measure, and competitor activity confounds the market situation. In all three, quality, advertising and promotion, management objectives are to spend no more than what is required to obtain maximum profits over an extended period of time. Even if a product is designed with the highest possible quality to give prestige to the company or its other product lines, this prestige is undoubtedly desired to enhance the company's long term economic position. It is encouraging to note these similarities between quality, advertising and promotion, for this may encourage experts in market modeling to include product quality in their future work.

Considerable effort has been devoted to the study of consumer response to brand names. Studies of brand name preferences are profuse in the current literature and this has been a popular subject for M.I.T. graduate theses. Among the things a brand name stands for, one seemingly obvious factor is quality. If this is true, the studies of brand name might
be useful in the study of marketing effects of product quality.

C. OBJECTIVES OF THIS STUDY

The intent of this study was to formulate a model which would show the effects of variation in product quality on corporate profits. Presumably this model would be mathematical; however, other possibilities were not ruled out. To keep the problem within reasonable bounds it was limited to consumer goods priced below $25 per unit. It was recognized that quality cannot be considered by itself; customers probably respond to a relationship between quality and price. Numerous other factors affecting consumers' buying decisions will have to be accounted for either by assumptions or inclusion in the model.

There was no attempt to build a model that could be applied equally to all consumer goods markets. Each product and each manufacturer are unique. A study of more than one market was considered beyond the scope of this work, although it might serve as a logical extension.

Mention was made earlier of the possible relevance of advertising, promotion and brand name studies to product quality. Although worthy of pursuit, these studies were not used as a basis for this work.

This study was intended to cover the most general, single product situation with a simple instructive model. If adequate input data could be developed, such a model might be useful in helping corporate management make product design decisions affecting new product lines or changes to existing
lines. Even by using hypothecated data, it is possible to gain some insight into market behavior. This limited benefit is a step forward from the current knowledge which is primarily based on intuition and informally co-ordinated observations.

D. PROCEDURE

A library search of current literature on marketing models was the initial step in this study. Material was limited by the small number of books and journals available on the subject. These references provided two things, (1) an acquaintance with marketing, and (2) a general understanding of the use of marketing models. Chapter II is devoted to the material gained in this search.

The second phase of the project was to define the factor being studied, product quality. Chapter III discusses quality, both generally and specifically for this study. Whenever it was necessary to deal with specific product markets, household floor wax was used as the product. This choice was made simply on the basis of the need for a product with reasonably rational and predictable purchase decisions.

The next step was to construct a company profit model. A simple, algebraic representation of a manufacturer's profits was written; from this the maximum profit level was derived and studied. This work is discussed in Chapter IV.

A second modeling effort is presented in Chapter V. Predictions of market behavior were made by compiling the
predictions for several individual market segments. In relation to the company profit model, this model adds a more complete representation of a market situation, and it provides greater opportunity to gain insight into market behavior.

In Chapter VI the segmented market model is further developed to account for a competitive situation. Several sets of circumstances are studied including expansion of a company line of products and entrance into a competitive market for the first time.

Finally, an attempt was made to test the models using data from a company manufacturing consumer products. Since data are limited, this work becomes a "test of reasonableness" rather than a rigorous evaluation. Chapter VII discusses the model testing effort.

E. SUMMARY

Increased competition among manufacturers and increased customer purchasing power are resulting in the emergence of product quality as an important manufacturing decision variable. Quality by itself is an inadequate concept to study; customers consider quality in relation to price as they make purchasing decisions. Although customers are willing to pay for improved quality, there is a point of diminishing returns beyond which increased expense for quality will no longer give proportionate increases in corporate profits.

Most of the work on mathematical models in marketing has been published since 1960. Among the numerous publications
only one article has been found pertaining to product quality; many are related to advertising, promotion and brand name preferences. While the avoidance of quality by marketing model experts suggests that it might be unrewarding, the subject seems far from imponderable and worthy of pursuit. Accordingly the objective of this study is to formulate a mathematical marketing model which will provide insight into the role of product quality in marketing activities.
Chapter II

MARKETING MODELS

A. DEFINITIONS

Many people have ventured to define a model. Paul Meadows said, "Every model is a pattern of symbols, rules and processes regarded as matching in part or in totality an existing perceptual complex." ¹ Harry Lipson offered the following definition: "Models are a simplified framework of an operation, representing only those aspects which are of primary importance to the problem under study." ² Another definition worthy of note was given by William Lazer--"A marketing model involves translating perceived marketing relationships into constructs, symbols and perhaps mathematical terms. . . . All marketing models are based on suppositions or assumptions. These assumptions do not correspond exactly with the real marketing world. Usually they are employed to simplify." ³ The above sequence of definitions moves from the general to the specific, with each definition contributing significantly to a better understanding of models.


Meadows offers the thought of symbolizing a perceived complex. By means of symbols, the scientist can convert a perceptual complex into conceptual order. In this process he ventures into varying degrees of abstractness using symbols to formulate models of reality. The better the model represents reality, the more valuable it will be. Thus, the value of a model is dependent on the symbolization process. In representing reality a model offers valuable insight which is useful only if the experimenter is mindful of the relevant reality not accounted for by the model. Lazer points out that "the greater the level of symbolization, the fewer the restrictions and the more adequate and more generally applicable the model."4

Lipson's definition contributes the thought that a model represents only those aspects which are of primary importance to the problem under study. Here is the implication that the problem is to be studied and the factors of primary importance selected. This selection process is perhaps more important than any subsequent work done with the model. Not only is it important in providing proper design of the model, but it requires a systematic analysis and formalization of the problem. The formalization process yields an understanding of the system necessary for intelligent application of the model.

Lazer, in his definition, introduces the important matter of assumptions in models. Freedom to make assumptions opens the door to the use of models. Without assumptions, models would be too complex and burdened with details to be

workable, if it were possible to properly represent all pertinent factors. A more likely situation is that without assumptions model builders would be stopped by their inability to properly account for all important factors. With the freedom to make assumptions comes a requirement that they be adequate for the purpose at hand. While a model is a means for testing hypotheses, the relevance of the test to reality depends on the assumptions.

B. NEED FOR MODELS

History

Discussion of the use of models has been prevalent in recent years; however, models have been in use for centuries. Analytical people tend to think in terms of systems, and systems are models. For example, scientists use mathematical constructs to represent the reality of physical laws. Sociologists use models in analyzing and predicting human behavior. Scientists in electronics and chemistry have long used models to represent action too minute to see. Thus, models are not a new invention; they are the result of a new and vigorous effort of applying long used principles to new areas.

Paul Meadows describes the organic image (Greek in origin) as the dominant model of system analysis. In the organism model all things are dependent on one another within the system. It is a hierarchal order of open systems which give up matter to and take matter from the environment in a condition of steady state. These concepts of systems and mutual inter-

\footnote{Meadows, \textit{op. cit.}, p. 6.}
dependence will apply almost universally in model structures.

Need for Rigorous Approach

Since barter and trade first began, marketing has become increasingly complex. Edward C. Bursk in *Text and Cases in Management* lists 10 ways increased complexity has come about:

1. The buyer-seller relationship has become more subtle.
2. There are numerous buyers out of direct control of the seller.
3. The seller has many ways of selling.
4. The seller has limited information on the relative potential of approaches at his disposal.
5. General social and economic conditions are changing.
6. Competitors are actively at work.
7. Buyers have their basic needs fulfilled.
8. Differences among products are subtle.
9. Product copying has become commonplace.
10. Heavy factory investments have led to more standardization which customers dislike.

An important characteristic of marketing is competition. In addition to the nearly predictable, stationary forces of the market, there are the unpredictable, strategic moves of competitors to which a marketing department must react.

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Competitor action limits the reliability of interpreting market changes that follow a deliberate change in marketing policy. Thus, two serious risks facing most marketing programs are (1) the risk of poor customer acceptance and (2) the risk of being dwarfed by competitors. Even a rigorous mathematical approach is limited for the marketing task; however, until a better approach is known, effort will undoubtedly continue to get the most usefulness from existing techniques.

C. MODELS IN COMMON USE

Types of Models

Lazer illustrates the types of models by a series of dichotomies as follows: 7

1. Mathematical versus loose verbal
2. Difference equation versus differential equation
3. Physical versus abstract
4. Dynamic versus static
5. Deterministic versus stochastic
6. Micromarketing versus macromarketing
7. Linear versus nonlinear
8. Goal versus systems

Some of the more rigorous models have come from research in such areas as:

1. Decision theory
2. Organization theory

7Lazer, op. cit., p. 12.
3. Game theory  
4. Operations research  
5. Linear programming  

These are all well established scientific tools making extensive use of mathematics. Considerable interest has been shown in the use of game theory, a formulation of optimal strategy. Marketing people are interested in game theory because it provides a way of dealing with variables having unpredictable properties but about which probability statements can be made.

Choice of the model type depends on the nature of the problem and the desired result. For instance, a linear model is simpler than nonlinear, but it will generally give a poorer fit to reality. Situations which do not warrant the higher precision of a nonlinear fit may benefit from the simplicity of a linear model.

Uses of Models

The literature abounds with general statements on the uses of marketing models. To a large degree the several writers appear to be saying the same thing with different words. Those uses which are most frequently mentioned are:

1. Aid development of marketing theories  
2. Problem solving  
3. Market research and experimental design  
4. Measure market effectiveness  
5. Forecasting
The above list is very general; it suggests that most areas of marketing have possible uses for models. Earlier, under Definitions, models were described as a formulation process for representing reality through the use of symbols and assumptions. If this definition is appropriate, extensive application of models in marketing may eventually be realized.

Many early and current applications of models were for simulating physical flow of goods in distribution systems. Optimum control of inventory and selling expenses are benefits of these models. More abstract and less precise models have been developed to study individual and aggregate human behavior in relation to such things as the buying decision and response to advertising. The abstract models are complementary to the physical models in that they relate to separate activities of marketing and their benefits should be additive.

It has been written that a good model will have: 8

1. Workability—assumptions fit
2. Simplicity—minimum number of assumptions
3. Generality—a number of outcomes can be predicted from the assumptions

Regardless of its use, a model seriously lacking in any of these properties is likely to have little value except those benefits derived in the process of formalizing the model.

D. MARKETING STRATEGY

Marketing includes all the activities concerned with getting products from manufacturer to the consumer. Studies have shown that approximately 50 percent of the consumer's dollar is spent for distribution.\(^9\) Competition, risk and continual change are characteristic problems of this immense function.

Marketing people are faced with the problem of determining the optimal method and cost of reducing, as much as possible, the uncertainties from inadequate data. Uncertainties suggest strategy; marketing strategy depends on the nature of the firm, the competition and the market. Different firms producing the same product might require different strategy because of differences in financial condition, customers' goodwill or performance capabilities. Competitive changes in price, advertising, personal selling and product quality will be met differently by different firms. Likewise, similar firms in different geographic areas may require different strategy because of differences in labor markets, transportation, local regulations and product markets. Large metropolitan markets are extremely sensitive to price, whereas small cities and towns are sensitive to the number and quality of dealers.\(^10\)

\(^10\)Bursk, op. cit., p. 41.
Such diversity among firms requires an over-all measure of performance if a comparison among firms or plants is desired. Measurements of specific performance factors such as distribution costs or gross sales could give misleading comparisons. Furthermore, the outcome of actions by one firm cannot be used to predict results from similar actions by a competitor. These are some of the reasons for measuring effectiveness of the total firm by means of profits or return on investment.

E. APPLICATION OF MATHEMATICAL MODELS TO MARKETING

Lazer gave four benefits of mathematical systems models for marketing:\textsuperscript{11}

1. Clarifies relationships and interactions
2. Promotes greater ease of communications
3. Adds objectivity
4. Makes analysis possible

Converting from verbal expression to a mathematical representation is difficult, but the rewards are often increased understanding of the concepts and operations involved. Mathematics in place of verbal structure reduces the possibilities of erroneous interpretations by observers and participants. Interrelationships and logic are difficult to maintain while manipulating a verbal model; with mathematics such maintenance is inherent. As mentioned earlier, these benefits are dependent upon and limited by assumptions which permit a mathematical representation of a complex situation.

\textsuperscript{11}Lazer, \textit{op. cit.}, p. 14.
F. SUMMARY

A model is a formalization process of selected aspects of reality through the use of symbols and assumptions. People have been using models for centuries; scientists depend heavily on their ability to simulate a system with symbols and rules. Marketing, because of its complexity, has much to gain by the use of models. It would be wrong to encourage a stereotype image of models, for they exist in a variety of mathematical and verbal forms.

Marketing is enormous in scope, consuming approximately one-half of the consumer's dollar. It is made up of firms that require different strategies because of internal and environmental differences. Mathematical models are well suited for this complex function. Such models permit analysis and manipulation while preserving interrelationships and logic in a language that has common understanding.
Chapter III

PRODUCT QUALITY

A. CUSTOMER'S CONCEPT OF QUALITY

One brief, sweeping definition of quality is, "any aspect of a product which influences the demand curve (including the services included in the contract of sales)."\(^1\) It is difficult to give a more specific definition without being limited to a more specific product-market description. Some of the more common product characteristics which have a quality aspect can be listed in three groups as follows:

<table>
<thead>
<tr>
<th>Sensory</th>
<th>Performance</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>appearance</td>
<td>efficiency</td>
<td>availability</td>
</tr>
<tr>
<td>taste</td>
<td>maintenance</td>
<td>proficiency</td>
</tr>
<tr>
<td>smell</td>
<td>lifetime</td>
<td></td>
</tr>
<tr>
<td>sound</td>
<td>output quality</td>
<td></td>
</tr>
<tr>
<td>feel</td>
<td>ease of use</td>
<td></td>
</tr>
<tr>
<td></td>
<td>accessories</td>
<td></td>
</tr>
<tr>
<td></td>
<td>compatibility</td>
<td></td>
</tr>
</tbody>
</table>

Each customer will place relative emphasis on the above factors in accordance with his own wants or needs. For this reason, product quality will mean different things to different

people. In addition to variation in their definitions of what constitutes quality, customers will also vary in the value they place on quality. If customers were all alike in their perception and valuation of quality, the marketplace would not have the existing multitude of competing products.

Although customers make a decision to accept certain product quality each time they purchase, the decision may not always be in their best interest. First-time purchases must be based on information from other than personal experience. Repeat purchases may be governed by brand loyalty without trial of competing products. A strong influence on many purchases is the direct selling effort. In many cases the dealer and salesman perform a valuable service in helping customers fit their needs. Unfortunately, however, the dealer too often bases promotion on his margin, resulting in customer purchases which maximize dealer profits but not customer satisfaction. Many private brands fall in the latter category. A person with expert knowledge on a group of products can make an interesting study in dealer promotion based on margin by "shopping" at a number of dealers.

Manufacturers facing a variety of forces that influence customer product-quality decisions often rely on empirical methods to predict market performance of a product. The familiar market test prior to introduction of a product is an example of such a method.

The previous discussion applies to considerations involved in each product purchase decision. Equally important
to the customer making repeat purchases is his assurance that a product will be consistently of the same quality. In food lines, for instance, if a customer experiences one or two distasteful units for each truly high quality unit, he may switch to a product line which has mediocre but consistent quality. Consistency of quality among a manufacturer's various product lines can similarly influence customer purchases by the phenomenon of brand loyalty. Recognition of the value of brand quality consistency is probably the motivation for distinguishing different quality brands such as Sears Roebuck's Dunlap and Craftsman lines. The engineering science "Quality Control" is perhaps best known for its contribution to improved consistency of product quality.

B. MANUFACTURING CONSIDERATIONS

The important test of the value of product quality is its effect on the market. Corporate profits will depend on the aggregate of all the individual courses of action taken by customers. Individually, customers faced with unsatisfactory quality may do any of a number of things depending on their particular circumstances. They may switch brands, "upgrade" to a higher quality line or switch to another product which will serve the same end. For nonstaple products in a competitive market, customers may simply buy less or not at all.

Customers may take over the initiative in assuring satisfactory quality by insisting upon a set of product specifications. This practice is prevalent in industrial and
government purchasing. Individual consumers can effectively utilize product specifications also. For instance, purchases of food, fabrics and automobiles easily lend themselves to an intelligent examination of specifications by individuals.

Although a manufacturer may have difficulty measuring the quality in a subjective sense, he can usually measure it in terms of manufacturing cost. Except for the development costs of introducing improved products, quality costs are variable. Manufacturing costs necessary to maintain high quality may include more costly raw materials, more labor, more costly processing, or more testing and waste. It is conceivable that for many consumer products the quality cost is greater than other manufacturing costs combined. The manufacturer of such a product, who agrees with the concept of diminishing returns for quality expense, will be anxious to know how to determine the quality level at which his profits will be maximized.

C. SUMMARY

Quality can be defined as any aspect of the product which affects its demand. Usually it is helpful to think in more specific terms under categories of sensory qualities, performance characteristics and services supplied.

Different customers will perceive quality differently and place different values on it. Many quality decisions by customers are unwise because of inadequate or inaccurate product information. On repeat purchase items, consistency of quality for a single product or among products in a brand can
be important to customers. They may respond with brand loyalty.

In a competitive market, customers can "vote" for their quality preferences by brand switching or discontinued buying. A knowledgeable customer may insist on product specifications as a guarantee of consistently satisfactory quality.

Manufacturing quality costs are variable; an alert manager will know these costs and will be intent on keeping them at an optimum level.
Chapter IV

A COMPANY PROFIT MODEL

A. COMPANY PROFITS EQUATION

Company profits can be represented by a simplified formula as follows:

\[ P = S(p - m - q) - M - A \]  \hspace{1cm} (1)

where:

- \( P \) = profits in dollars
- \( S \) = sales in units
- \( p \) = price in dollars per unit
- \( m \) = variable manufacturing cost in dollars per unit
- \( q \) = variable quality cost in dollars per unit. Customer satisfaction will bear some relation to \( q \); however, an increase in \( q \) need not always increase customer satisfaction
- \( M \) = fixed manufacturing costs in dollars
- \( A \) = fixed advertising cost in dollars

The expression \( (p - m - q) \) can be thought of as variable profit per unit since it measures unit profit before subtracting fixed costs of manufacturing and advertising.

For purposes of this model, sales will be considered as a function of price, quality and advertising:
Price is considered set by management to be some function of manufacturing fixed and variable costs, quality costs, and advertising costs:

\[ p = p(m, q, M, A) \] (3)

There are two extremes in thinking of fixed manufacturing and advertising costs for equation (3). One is that these costs are fixed for all sales levels indefinitely, while the other is that they are fixed only over short time intervals. For this study, M and A are considered fixed over the time interval of interest. Equation (3) is interpreted as: "Price is some as yet undefined function of manufacturing fixed and variable costs and advertising fixed costs."

Equation (1) can now be rewritten substituting equations (2) and (3) for S and p respectively:

\[ P = S[p(m, q, M, A), q, A] \left[ p(m, q, M, A) - m - q \right] - M - A \] (4)

Equation (4) shows profits in terms of quality, manufacturing and advertising costs. Manufacturing and advertising costs m, M and A are all constants, and q is variable.

B. REPRESENTATION OF THE MAXIMUM PROFIT POSITION

Derivation

Taking the first derivative of equation (4) with respect to q and setting it equal to zero will define conditions at the maximum profit level.
\[
\frac{dP}{dq} = \left[ \frac{\partial S}{\partial p} \frac{dp}{dq} + \frac{\partial S}{\partial q} \right] (p - m - q) + S \left[ \frac{dp}{dq} - 1 \right] = 0 \tag{5}
\]

Clearing parentheses gives:

\[
\frac{\partial S}{\partial p} \frac{dp}{dq} (p - m - q) + \frac{\partial S}{\partial q} (p - m - q) + \frac{dp}{dq} S - S = 0
\]

Rearranging:

\[
\frac{\partial S}{\partial q} (p - m - q) - S = - \frac{dp}{dq} S - \frac{\partial S}{\partial p} \frac{dp}{dq} (p - m - q)
\]

Dividing by \((p - m - q)\):

\[
\frac{\partial S}{\partial q} - \frac{S}{(p - m - q)} = - \frac{dp}{dq} \frac{S}{(p - m - q)} - \frac{\partial S}{\partial p} \frac{dp}{dq}
\]

Rearranging:

\[
\frac{\partial S}{\partial q} - \frac{S}{(p - m - q)} = \frac{dp}{dq} \left[ - \frac{\partial S}{\partial p} - \frac{S}{(p - m - q)} \right] \tag{6}
\]

The following work in this chapter assumes that equation (6) represents the true maximum profit position. A test for
maximum can be obtained by taking the second derivative of the
profits equation with respect to quality. If this function is
negative, the first derivative represents a true maximum. Using
a general equation such as (5) results in a second derivative
which cannot be interpreted as positive or negative without
assuming specific forms for the functions involved. Therefore,
verification of a maximum is attempted by reasoning as follows:
Consider a low quality product which has a minimum market ap-
peal. Assume that the company operates with constant margin.¹
Quality increases will bring increased sales until the price
becomes prohibitive to many customers. At very high prices,
sales will be lower regardless of the high quality. These
characteristics will be seen in the model in Chapter VI where
the maximum profit position is determined graphically.

Discussion of Derivatives

Equation (6) is a useful form for examining conditions
at the maximum profit position. Preparatory to such examina-
tion, a discussion of the interpretation of the three deriva-
tives included in equation (6) is desirable.

The partial derivative \( \frac{\partial s}{\partial q} \) is the change in sales for
a small change in quality, or the "sales response to quality." Under normal circumstances \( \frac{\partial s}{\partial q} \) will be positive assuming that
the aggregate effect of improved quality is always favorable
to customers. At the level of diminishing returns for quality

¹Throughout this study the term "margin" will be used as "the percent of selling price which is profit."
expense $\frac{\partial S}{\partial q}$ might approach zero.

Similar to the sales-response-to-quality expression, there is a "sales response to price" factor $\frac{\partial S}{\partial p}$. This partial derivative represents the change in sales resulting from changes in price. Normally $\frac{\partial S}{\partial p}$ will be negative but it could be zero for products with inelastic demand. Staple household products such as salt, sugar, shortening and flour probably have $\frac{\partial S}{\partial p}$ values close to zero for product sales in total.

Pricing policy will determine the value of $\frac{\partial p}{\partial q}$. This derivative represents the change in price for a small change in quality cost. Normally $\frac{\partial p}{\partial q}$ will be zero or positive in value. If it is zero, price is constant for various levels of quality. A value of one for $\frac{\partial p}{\partial q}$ means that price is varied directly with cost of quality without any profit being made on the variable cost of quality. Values above one provide for profit on the element of quality cost. For instance, a value of 1.5 for $\frac{\partial p}{\partial q}$ means that quality cost is "marked up" 50 percent. These different pricing policies will be examined at the maximum profit level shown by the model.

C. MAXIMUM PROFITS UNDER VARIOUS PRICING POLICIES

Price Constant for All Quality Levels

Using equation (6), $\frac{\partial p}{\partial q}$ can be set equal to zero to study the constant price situation. This gives:

$$\frac{\partial S}{\partial q} - \frac{S}{(p - m - q)} = 0$$
or:
\[
\frac{\partial S}{\partial q} = \frac{S}{p - m - q}
\]  

Equation (7) states that, at the maximum profits position with constant price, the sales response to quality equals sales divided by variable profit.

Considering price constant allows us to treat the partial derivative \(\frac{\partial S}{\partial q}\) as the total derivative \(\frac{dS}{dq}\). Then, rewriting equation (7) in differential form gives a more meaningful expression:

\[
S \, dq = (p - m - q) \, dS
\]

The above expression indicates that, at the maximum profit position with constant price, the total incremental cost for a quality change \(S \, dq\) is equal to the incremental revenue resulting from the quality change. This is the familiar economist's criterion of marginal cost equal to marginal revenue for maximum profits.

**Variable Cost of Quality Passed on to the Customer**

To consider the situation where the manufacturer passes on his variable quality cost to the customer at cost (no profit or loss on variable quality cost), \(\frac{dp}{dq}\) is set equal to 1. Then equation (6) becomes:

\[
\frac{\partial S}{\partial q} - \frac{S}{p - m - q} = -\frac{\partial S}{\partial p} - \frac{S}{p - m - q}
\]
or: \[ \frac{\partial S}{\partial q} = - \frac{\partial S}{\partial p} \] (8)

Equation (8) can be interpreted that the increase in sales resulting from a small increase in quality will equal the decrease in sales resulting from the increase in price required to offset the quality cost. This equality of sales responses is similar to the marginal revenue equal to the marginal cost concept. For a change in quality and price, sales gained must equal sales lost.

Manufacturer Shares Cost of Quality with the Customer

Consider now the situation where the manufacturer shares the cost of increased quality with the customer by making price increases smaller than the incremental increase in quality cost. Under these circumstances: \( 0 < \frac{\partial p}{\partial q} < 1 \). Equation (6) then becomes:

\[ \frac{\partial S}{\partial q} - \frac{S}{p - m - q} < - \frac{\partial S}{\partial p} - \frac{S}{p - m - q} \]

or: \[ \frac{\partial S}{\partial q} < - \frac{\partial S}{\partial p} \] (9)

Thus, if the manufacturer shares the incremental cost of quality increases with his customers, his maximum profit position will be characterized by a sales response to quality smaller than the negative sales response to price.
Customer Pays a Profit on the Cost of Quality

The next pricing policy to be considered is \( 1 < \frac{dp}{dq} \). In this case the manufacturer is making a profit on each additional increment of quality cost incorporated in the product. Equation (6) becomes:

\[
\frac{\partial S}{\partial q} - \frac{S}{p - m - q} > - \frac{\partial S}{\partial p} - \frac{S}{p - m - q}
\]

or:

\[
\frac{\partial S}{\partial q} > - \frac{\partial S}{\partial p}
\]

Thus, if a company chooses to charge its customers a profit on increments of increased quality, its sales response to quality will be greater than the negative sales response to price at the maximum profit position.

Price Independent of Cost of Quality

Each of the above four pricing policies assumes that cost of quality will be one of the determinents of price. In those cases quality is an independent variable and price is a specified function of quality and other variables. The final pricing policy to be considered with this model is one in which both price and quality are independent variables.

Since \( q \) and \( p \) are independent, the equation determining optimum quality is valid for all possible values of \( \frac{dp}{dq} \). Therefore it follows that each side of equation (6) must be equal to zero.
Then: \[
\frac{\partial S}{\partial q} = \frac{S}{p - m - q} \quad \text{or} \quad S \, dq = (p - m - q) \, dS \quad (11)
\]

when \( p \) is constant at its optimal value

\[
\frac{\partial S}{\partial p} = \frac{S}{p - m - q} \quad \text{or} \quad S \, dp = -(p - m - q) \, dS \quad (12)
\]

when \( q \) is constant at its optimal value

and \[
\frac{\partial S}{\partial q} = - \frac{\partial S}{\partial p} \quad (13)
\]

From equations (11), (12), and (13) the following statements can be made in regard to the maximum profits position when price and quality vary independently:

1. The marginal revenue from sales stimulated by increased quality equals the marginal cost of the increase in quality.

2. The marginal revenue lost from the decrease in sales due to a price increase equals the marginal revenue gained by the higher price.

3. The sales gained per unit of increased cost of quality equals the sales lost per unit of increase in price.

The above results can also be obtained by writing a new model equation for profits with price and quality as independent variables. Partial derivatives are then taken with respect to price and quality. These partial derivatives set equal to zero give equations (11) and (12).
D. PRACTICAL PROBLEMS

How can a company know what their sales responses to quality and price are? Obviously, if they are to get maximum benefit from statements such as those given above, they need to know their sales responses as accurately as possible. Experienced members of the sales department may have a good perception of these values, but it is difficult to put them in quantitative terms. Historical data should be examined for instances where price or quality varied independent of other factors. Even in these instances the data are usually confounded by such things as product growth and competitor activities. Ideally the best alternative might be to conduct market experiments by making intentional changes in price and quality while other factors are held constant. In a practical sense, such experiments may be very difficult to conduct. Unfortunately it must be agreed that current knowledge cannot adequately prescribe how to obtain the marketing information needed.

Market experiments have been run to study effects of advertising and promotion, an accomplishment not thought possible a few years ago. Similar methods may prove useful for measuring sales response to quality. Sales response to price is understood intuitively, and in some cases fairly quantitatively, by many companies today; market experience with price changes is usually carefully watched by marketing personnel. A final word of caution is necessary; sales response determi-
nations can become obsolete. Changes in the economy and the competitive position of the company can alter consumer buying decisions considerably.

E. SUMMARY

A relatively simple mathematical equation for company profits has been constructed as a function of sales, price, quality and operating costs. From this equation, a mathematical expression was derived to represent conditions at the maximum profit position of the company.

Market characteristics at the maximum profit position can be shown for five pricing policies as follows:

1. Constant price--Incremental cost of increasing quality equals incremental revenue derived from the resulting higher sales.

2. Quality cost passed on to the customer--The gain in sales resulting from an incremental quality improvement equals the sales loss resulting from the price increase required to cover the quality cost.

3. Manufacturer shares quality cost with the customer--The sales gained from an incremental quality increase will be less than the sales lost from the associated increase in price.

4. Manufacturer charges a profit on the cost of quality--The sales gained from an incremental increase in quality will be greater than the sales lost from the associated increase in price.
5. Manufacturer sets price independent of quality cost--
a) marginal revenue from increased quality equals
marginal cost of the quality increase.
b) marginal revenue from increased price equals
marginal revenue lost by the decrease in sales.
c) sales gained per unit of increased quality cost
equals the sales lost per unit of increased
price.

If a manufacturer is to benefit from the above five
statements, he needs a means of estimating his sales response
to price and quality. Here lies a very significant problem;
most methods have inherent inaccuracies. Historical data are
confounded with other factors, while market experiments may be
very difficult to conduct. In truth there is no currently
known satisfactory procedure for obtaining the desired market-
ing data in the detail desired.
Chapter V

A SEGMENTED MARKET MODEL

A. INTRODUCTION

In Chapter IV it was observed that the mathematical test for a true maximum of profits required assumptions for some of the functions in the profits equation. Specifically, it is necessary to know the relationship between sales, quality and price. In an industrial situation these relationships must be found by experience or experimentation, whereas for this model they will be chosen a priori.

The total market for a product is composed of many different types of people with different approaches to the buying decision. A prediction of the buying practices of one group within the market would be more accurate than a prediction of the total market. Using this premise, the accuracy of a product market prediction is enhanced by taking the summation of predictions for each of the several groups within the market.

The mathematical derivations of Chapter IV were not limited to a specific product or type of product. Conclusions from the mathematical derivations are thus equally applicable to any product for which the assumed sales, price and profits equations apply.

The model to be developed in this chapter requires a
more specific definition of products; the reward will be more specific results. A household floor wax with general market acceptance was the assumed product used to establish the consumer buying practices. Of course the model will be equally applicable to any other products that have the same consumer price and quality responses as floor wax.

B. EXAMINATION OF THE MARKET SYSTEM

A consumer product market system can be thought of as containing six groups of activity: (1) manufacturing, (2) distribution, (3) retailing or point of sale, (4) customer, (5) forces of company origin which affect the customer's decision, and (6) environmental forces which affect the customer's decision. Table I shows these six activity groups in detail. Marketing people will consider all the factors listed in Table I and many other factors not listed. Any given consumer product will have emphasis concentrated in specific areas although not to the exclusion of the others. Floor wax, for example, might have emphasis on appearance, convenient outlets, salesman product knowledge, housewives, company reputation and relative independence of general economy. Manufacturers of floor wax would be unwise to limit their efforts to only these factors however, because their product market requires some concern for all of the items in Table I. On the other hand, specialized products with a limited market may be satisfactorily handled with a narrow marketing emphasis.

Table I would have greater meaning if the interrelation
### TABLE I
THE MARKET SYSTEM

<table>
<thead>
<tr>
<th>POINT OF SALE</th>
<th>CUSTOMER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Package</td>
<td>1. Institutional</td>
</tr>
<tr>
<td>a. Protection</td>
<td>a. Industrial</td>
</tr>
<tr>
<td>b. Convenience</td>
<td>b. Commercial</td>
</tr>
<tr>
<td>c. Attractiveness</td>
<td>c. Public</td>
</tr>
<tr>
<td>d. Identification</td>
<td>d. Private</td>
</tr>
<tr>
<td>2. Display</td>
<td>2. Individual</td>
</tr>
<tr>
<td>a. Planned buying</td>
<td>a. Sex</td>
</tr>
<tr>
<td>b. Impulse buying</td>
<td>b. Age</td>
</tr>
<tr>
<td>3. Selling Method</td>
<td>c. Education</td>
</tr>
<tr>
<td>a. Inspection</td>
<td>d. Social status</td>
</tr>
<tr>
<td>b. Sampling</td>
<td>e. Family size</td>
</tr>
<tr>
<td>c. Description</td>
<td>f. Occupation</td>
</tr>
<tr>
<td>4. Salesman</td>
<td>g. Income</td>
</tr>
<tr>
<td>a. Product knowledge</td>
<td>h. National origin</td>
</tr>
<tr>
<td>b. Style</td>
<td>i. Residence</td>
</tr>
<tr>
<td>5. Competition Products</td>
<td>rural</td>
</tr>
<tr>
<td>a. Number</td>
<td>urban</td>
</tr>
<tr>
<td>b. Differentiation</td>
<td>j. Religion</td>
</tr>
<tr>
<td>6. Promotion devices</td>
<td></td>
</tr>
<tr>
<td>a. Coupons</td>
<td></td>
</tr>
<tr>
<td>b. Stamps</td>
<td></td>
</tr>
<tr>
<td>c. Give-aways</td>
<td></td>
</tr>
<tr>
<td>7. Price</td>
<td></td>
</tr>
<tr>
<td>a. Discounts</td>
<td></td>
</tr>
<tr>
<td>b. Allowances</td>
<td></td>
</tr>
<tr>
<td>c. Service charges</td>
<td></td>
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<tr>
<td>d. Stability</td>
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</tbody>
</table>
among groups of activities were shown. Some of the activities are dependent upon others, while some affect the market system independently. Figure 1 shows diagrammatically the manner in which the activities from Table I are interrelated. Figure 1 suggests three sources of information influencing the customer: knowledge of the manufacturer, general economy, and information at the point of sale. Naturally, all these sources of information are not functioning for all customers on all purchasing occasions; moreover, when information sources are influencing customers it may be a subconscious effect.

If model complexity were not a deterrent, all the factors listed in Table I could be studied at once. Such an undertaking, although possible, is beyond the scope of this study. The alternative chosen here was to assume all factors except quality and price to have constant effects on the product market. This simplifying assumption provides ease and flexibility for the exploratory process of model building. It might be worth while to add complexity in subsequent studies where the modeling procedure is predetermined and well understood.

The activity depicted in Figure 1 will vary with time. Advertising, for instance, may not produce immediate effects on the customer. In general, the three information sources which the customer responds to will not serve the customer simultaneously. For purposes of this study, it is assumed that only conditions over long-time intervals will be of interest. Thus, factors which vary with time will be considered at
FIGURE 1
THE MARKET SYSTEM
their average levels. This assumption is supported by the fact that normally long-time intervals elapse between manufacturers' price or quality changes for consumer products.

C. MARKET COMPOSITION

The Life Study of Consumer Expenditures\(^1\) gives household expenditures in the United States according to groupings of family size, geographic location, occupation, income level and urban-rural living. Each group is divided into several categories. These data were used to derive sources of household spending for operation within each grouping as follows:

\[ H_{ij} = \text{Source (percent) of all U.S. spending for household operation from the } i\text{th grouping and } j\text{th category} \]

\[ N_{ij} = \text{Number of households in the } i\text{th grouping and } j\text{th category} \]

\[ E_{ij} = \text{Average annual total household expense for the } i\text{th grouping and } j\text{th category in dollars} \]

\[ P_{ij} = \text{Percent of household expenses in the } i\text{th grouping and } j\text{th category which go for operation} \]

\[ H_{ij} = \frac{N_{ij} \cdot E_{ij} \cdot P_{ij} \times 100}{\sum_j N_{ij} \cdot E_{ij} \cdot P_{ij}} \quad \text{(for a given } i) \quad (1) \]

Table II shows the results of the above calculations. To interpret Table II, one should keep in mind that any individual's spending must fall in one category of each of the five main groupings. For instance, a person could be from:

1. Rural, less than 2,500 population
2. Under $2,000 income
3. Professional occupation
4. Living in the West
5. Having younger children

To proceed with a model using all combinations of categories of Table II would require consideration of 6,720 combinations in total. Clearly, the use of 6,720 combinations entails more time than is available and may offer little benefits over a smaller number of combinations. By elimination of certain groups and categories, Table II was reduced to Table III, giving a breakdown which seems reasonable and yet can conveniently be handled.
TABLE II

SOURCES OF SPENDING FOR HOUSEHOLD OPERATION

1. Urban - Rural

<table>
<thead>
<tr>
<th>Source</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td></td>
</tr>
<tr>
<td>less than 2500 population</td>
<td>16.8</td>
</tr>
<tr>
<td>more than 2500 population</td>
<td>13.7</td>
</tr>
<tr>
<td>Urban - less than 500,000 population</td>
<td></td>
</tr>
<tr>
<td>central cities</td>
<td>11.9</td>
</tr>
<tr>
<td>other areas</td>
<td>12.1</td>
</tr>
<tr>
<td>Urban - more than 500,000 population</td>
<td></td>
</tr>
<tr>
<td>central cities</td>
<td>24.4</td>
</tr>
<tr>
<td>other areas</td>
<td>21.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

2. Income level

<table>
<thead>
<tr>
<th>Income Level</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under $2000</td>
<td>7.6</td>
</tr>
<tr>
<td>2000 - 2999</td>
<td>11.0</td>
</tr>
<tr>
<td>3000 - 3999</td>
<td>13.8</td>
</tr>
<tr>
<td>4000 - 4999</td>
<td>20.5</td>
</tr>
<tr>
<td>5000 - 6999</td>
<td>24.6</td>
</tr>
<tr>
<td>7000 - 9999</td>
<td>13.6</td>
</tr>
<tr>
<td>10000 and over</td>
<td>8.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

3. Occupation

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional, semi-professional</td>
<td>12.6</td>
</tr>
<tr>
<td>Proprietor, manager, official</td>
<td>13.1</td>
</tr>
<tr>
<td>Clerical, sales</td>
<td>14.1</td>
</tr>
<tr>
<td>Craftsman, foreman</td>
<td>17.1</td>
</tr>
<tr>
<td>Operative</td>
<td>19.6</td>
</tr>
<tr>
<td>Service worker</td>
<td>5.6</td>
</tr>
<tr>
<td>Farmer, farm laborer</td>
<td>6.4</td>
</tr>
<tr>
<td>Retired, or head not employed</td>
<td>11.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

4. Geographic location

<table>
<thead>
<tr>
<th>Geographic Location</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western</td>
<td>15.2</td>
</tr>
<tr>
<td>Southern</td>
<td>22.0</td>
</tr>
<tr>
<td>Central</td>
<td>32.9</td>
</tr>
<tr>
<td>Northeast</td>
<td>29.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

5. Family size

<table>
<thead>
<tr>
<th>Family Size</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger children</td>
<td>47.8</td>
</tr>
<tr>
<td>Older children only</td>
<td>15.4</td>
</tr>
<tr>
<td>No children, head over 40 years old</td>
<td></td>
</tr>
<tr>
<td>Married head</td>
<td>19.6</td>
</tr>
<tr>
<td>Single head</td>
<td>9.2</td>
</tr>
<tr>
<td>No children, head under 40 years old</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>
TABLE III
Sources of Spending for Household Operation

1. Income Level
   a. Under $7,000  77%
   b. Over $7,000  23%

2. Occupation
   a. Professional  26%
   b. Skilled  31%
   c. Worker plus retired  43%

3. Family
   a. With children  63%
   b. Without children  37%

If it is assumed that the above attributes are independent, it is then possible to use Table III to determine the percentage of total spending in all possible combinations of categories. This is done by multiplying the three percentages for the categories which describe the source of spending. Thus, spending from (1) "Under $7,000," (2) "Professional" and (3) "With children" equals .77 times .26 times .63 or 12.6 percent of all spending for household operation in the United States. Although the independence assumption has obvious imperfections, it seems sufficiently good for the purposes here.

For simplicity, the group and category headings in Table III will be used to identify spending sources in future tables. For example, 2b is spending by skilled workers' families. Table IV shows the results of calculating spending for
all possible combinations of categories shown in Table III. Each entry includes a category from each of the three groupings and thus is a complete customer description. These customer descriptions will be called market segments; all consumers are included in the Table of 12 market segments. In order to simplify later expressions, the subscript \( t = 1_{j1}, 2_{j2}, 3_{j3} \) is introduced in Table IV.

### TABLE IV

**SOURCES OF SPENDING BY MARKET SEGMENTS**

<table>
<thead>
<tr>
<th>( t )</th>
<th>Market Segment (see Table III)</th>
<th>( H_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1a, 2a, 3a</td>
<td>.126</td>
</tr>
<tr>
<td>2</td>
<td>1a, 2a, 3b</td>
<td>.074</td>
</tr>
<tr>
<td>3</td>
<td>1a, 2b, 3a</td>
<td>.150</td>
</tr>
<tr>
<td>4</td>
<td>1a, 2b, 3b</td>
<td>.088</td>
</tr>
<tr>
<td>5</td>
<td>1a, 2c, 3a</td>
<td>.209</td>
</tr>
<tr>
<td>6</td>
<td>1a, 2c, 3b</td>
<td>.123</td>
</tr>
<tr>
<td>7</td>
<td>1b, 2a, 3a</td>
<td>.038</td>
</tr>
<tr>
<td>8</td>
<td>1b, 2a, 3b</td>
<td>.022</td>
</tr>
<tr>
<td>9</td>
<td>1b, 2b, 3a</td>
<td>.045</td>
</tr>
<tr>
<td>10</td>
<td>1b, 2b, 3b</td>
<td>.026</td>
</tr>
<tr>
<td>11</td>
<td>1b, 2c, 3a</td>
<td>.062</td>
</tr>
<tr>
<td>12</td>
<td>1b, 2c, 3b</td>
<td>.037</td>
</tr>
</tbody>
</table>

The entries in Table IV will be used in the model calculations which follow in this chapter.
D. DEVELOPMENT OF THE MODEL

Price and Quality Sensitivity of Market Segments

The objective here, as in Chapter IV, is to derive a statement of conditions which describe the maximum profit position of the company or describe market behavior at the maximum profit position. Profits will be assumed to bear some relationship to sales; thus, the starting point is to derive an expression to predict sales. Considering quality and price variations independently, potential sales for a given market segment will increase with increasing quality and decrease with increasing price. These relationships are taken as piecewise linear functions in this model. The sales potential for a market segment will be the product of independent price and quality contributions to the customer's incentive to buy.

Thus:

$$\text{Sales Potential for the } t\text{th Segment} = f_{1t}(p) f_{2t}(q) = s_t \quad (2)$$

where \(s_t\) is a percent of the possible sales for the segment and \(f_{1t}(p)\) and \(f_{2t}(q)\) are functions of price and quality respectively.

With linear relationships between sales potential and price, the functions \(f_{1t}\) for the several market segments are fixed by the lowest price at which sales potential is zero. This value is called \(\alpha_t\). For quality, the various \(f_{2t}\) functions are fixed by the lowest quality at which sales potential
is maximum. These values are called $\beta_t$.

$\alpha_t$ and $\beta_t$ are determined by adding three individual $\alpha_{ij}$ and $\beta_{ij}$ values to get $\alpha_t$ and $\beta_t$ for each market segment. While it would be very difficult to establish the segment $\alpha_t$ and $\beta_t$ values because of the combination of three consumer characteristics, it is relatively easy to estimate $\alpha_{ij}$ and $\beta_{ij}$ values for a single characteristic at a time assuming other factors constant. For this purpose $\alpha_{ij}$ and $\beta_{ij}$ are expressed as percent deviations from a reference value.

The values chosen for $\alpha_{ij}$ and $\beta_{ij}$ are shown in Table V.

<table>
<thead>
<tr>
<th>Consumer</th>
<th>$\alpha_{ij}$</th>
<th>$\beta_{ij}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Income</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Under $7,000</td>
<td>-.4</td>
<td>+.3</td>
</tr>
<tr>
<td>b. Over $7,000</td>
<td>+.5</td>
<td>-.1</td>
</tr>
<tr>
<td><strong>2. Occupation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Professional</td>
<td>+.3</td>
<td>-.4</td>
</tr>
<tr>
<td>b. Skilled</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>c. Worker plus retired</td>
<td>-.2</td>
<td>+.4</td>
</tr>
<tr>
<td><strong>3. Family</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. With children</td>
<td>+.2</td>
<td>-.3</td>
</tr>
<tr>
<td>b. Without children</td>
<td>0</td>
<td>+.1</td>
</tr>
</tbody>
</table>
High $\alpha_{ij}$ values denote consumers who are willing to pay a high price for the product. A high value for $\beta_{ij}$ denotes consumers who do not readily respond to quality improvements. An effort was made to choose $\alpha_{ij}$ and $\beta_{ij}$ values as percentage changes from a reference point and to have the magnitudes reasonable for the various consumer groups. Although it would be absurd to claim precision for $\alpha_{ij}$ and $\beta_{ij}$, it is probably realistic to claim that the consumer categories are in the proper position relative to each other. As already explained, it is assumed that the $\alpha_{ij}$ values are additive among the several categories. The same applies to the $\beta_{ij}$ values.

The $\alpha_{ij}$ and $\beta_{ij}$ values are not useful in a form as listed in Table V. Every customer has three $\alpha$'s and three $\beta$'s, one from each general grouping. Using the additivity assumption, $\alpha_t$ for the market segment $t = (l_{1j}, 2j_2, 3j_3)$ is:

$$\alpha_t = \alpha_{l_{1j}} + \alpha_{2j_2} + \alpha_{3j_3}$$  \hspace{1cm} (3)

and:

$$\beta_t = \beta_{l_{1j}} + \beta_{2j_2} + \beta_{3j_3}$$  \hspace{1cm} (4)

These calculations applied to each market segment yield the following table:
Equation for Estimating Sales

Using the values of $\alpha_t$ and $\beta_t$, sales potential curves with price and quality considered separately are drawn for each of the 12 market segments. These curves, shown in Figures 2 and 3, are the functions $f_{1t}(p)$ and $f_{2t}(q)$ shown in equation (2). In Figure 2 the $\alpha_t$ values are the price values at which the curves intercept the zero sales potential axis. The $\beta_t$ values in Figure 3 are the quality values at which the curves intercept the 1.0 sales potential axis. The price and quality

\[ \text{Table VI} \]

$\alpha_t$ and $\beta_t$ Values as Net Percentage Deviations from a Reference of 1.0

<table>
<thead>
<tr>
<th>$t$</th>
<th>$\alpha_t$</th>
<th>$\beta_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+ .1</td>
<td>- .4</td>
</tr>
<tr>
<td>2</td>
<td>- .1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>- .2</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>- .4</td>
<td>+ .4</td>
</tr>
<tr>
<td>5</td>
<td>- .4</td>
<td>+ .4</td>
</tr>
<tr>
<td>6</td>
<td>- .6</td>
<td>+ .8</td>
</tr>
<tr>
<td>7</td>
<td>+1.0</td>
<td>- .8</td>
</tr>
<tr>
<td>8</td>
<td>+ .8</td>
<td>- .4</td>
</tr>
<tr>
<td>9</td>
<td>+ .7</td>
<td>- .4</td>
</tr>
<tr>
<td>10</td>
<td>+ .5</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>+ .5</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>+ .3</td>
<td>+ .4</td>
</tr>
</tbody>
</table>
FIGURE 2. SALES POTENTIAL STIMULATED BY PRICE FOR EACH MARKET SEGMENT
FIGURE 3. SALES POTENTIAL STIMULATED BY QUALITY FOR EACH MARKET SEGMENT
scales in Figures 2 and 3 respectively are in terms of percent deviation from a reference of 1.0.

A few comments are in order with regard to the sales potential scale of \( f_{1t}(p) \), \( f_{2t}(q) \) and their product \( s_t \). A value of 1.0 means that the individuals will be sufficiently satisfied with quality or price to buy to the maximum of their needs or wants. Zero values signify conditions at which consumers find no satisfaction in the product and will thus buy none. If a consumer has zero potential sales due to quality, he will not buy at any price and similarly for zero potential sales due to price he will not buy at any quality level. Price must be very low and quality above the \( \beta_t \) level before a customer will buy to his limit. Unless a product is free, customers will ration their spending relative to other commodities and thus, on the average, will buy less than their maximum wants or needs. There is no intent to imply by Figures 2 and 3 that the true sales potential functions are linear; it is felt, however, that a linear estimate of these unknown, non-linear functions is as good for purposes of the model under study as non-linear estimates would be.

There is now enough information to determine the total sales potential for the entire market. Multiplying the results from equation (2) by the corresponding values in Table IV gives the fraction of all U.S. spending for household operations that is potentially available from that market segment. Then summing these products over the 12 segments gives the sales potential from the total U.S. market.
For a given price and quality level the total sales will be assumed to be given by:

\[
\text{Total Sales} = S = \sum_t s_t H_t = \sum_t f_{1t}(p) f_{2t}(q) H_t \quad (5)
\]

where values of \( H_t \) are given in Table IV

\( f_{1t}(p) \) is taken from the appropriate market segment line in Figure 2 at the existing price level.

\( f_{2t}(q) \) is taken from the appropriate market segment line in Figure 3 at the existing quality level.

Equation (5) can be used to determine potential total sales from the market for any combination of price and quality. As given in equation (5), \( S \) will be a fraction of the dollar market because the \( H \) values are based on fractions of household spending dollars available. Since the values of \( f_{1t} \) and \( f_{2t} \) are a measure of the fraction of the total possible sales, the value of \( S \) will likewise be in terms of the fraction of the total market theoretically obtainable. To obtain estimated sales in dollars, \( S \) should be multiplied by the total market expressed in dollars.

**Discussion of an Alternative Method**

The model is now complete as represented by equation (5). In the remainder of this chapter the results from equation (5) will be studied under a variety of circumstances. Before leaving this section, however, passing comment should
be made on an alternative model. Rather than the additive method described above for combining the $\alpha_{ij}$ and $\beta_{ij}$ values, a multiplicative method could be used. Of course, different $\alpha_{ij}$ and $\beta_{ij}$ values would be established (probably as decimals distributed about a value of 1.0). Rather than multiplying the $\alpha_{ij}$ and $\beta_{ij}$ for the three groupings, values of $f_1(p)$ and $f_2(q)$ are multiplied. Separate curves of $f_1$ and $f_2$ versus price and quality respectively are drawn for each of the seven values of $\alpha_{ij}$ and $\beta_{ij}$. The sales potential for a consumer segment is then the product of three $f_1(p)$ values and $f_2(q)$ values.

The multiplicative model has two chief disadvantages: first, it requires more laborious calculations, and second, it permits a zero sales potential for one category of a customer grouping to cause all market segments including that category to have zero sales potential. The latter characteristic is probably unrealistic. For instance, a high income retired family might still buy a product considering their income even though the price is too high from their viewpoint as in the retired category. The additive approach would show some sales potential due to the high income while the multiplicative method would give zero sales potential due to the zero $f_1(p)$ values from the retired category.

E. THE MAXIMUM PROFITS POSITION

The Total Sales Potential Surface

Profits are dependent on sales in a manner which varies
with the pricing policy. The simplest (and quite common) pricing policy uses a constant percent margin of profit. In this case, maximum profits and maximum dollar sales are coincident. Equation (5) provides a useful tool for estimating sales potential as a function of price and quality. By this means, sales potential calculations were made for 90 price-quality combinations. These results are shown in Table VII.

With one dependent and two independent variables, the model characteristics are easily analyzed in three-dimensional space. Price and quality can be considered as the two horizontal axes and sales potential as the vertical axis. Thus, all possible values of \( S \) will form a surface in \( 1/8 \) of the tri-coordinate space, that portion where \( p, q, \) and \( S \) are all positive. The contour of the \( S \) surface will be examined in three ways.

One of the easiest and most conventional ways of visualizing a three-dimensional surface is by passing planes through the surface parallel to two axes. Figure 4 shows the planer intercepts parallel to the quality and sales axes, while Figure 5 shows planer intercepts parallel to the price and sales axes. It is interesting to note that the piecewise linear plots of Figures 2 and 3 become smooth curves when added over the population as in Figures 4 and 5. Although these two families of curves aid in visualizing the sales function, it is perhaps more realistic to examine the sales function at constant percent margin.

Sales at constant margin were studied by assuming that
### TABLE VII

**TOTAL PRODUCT SALES POTENTIAL**

<table>
<thead>
<tr>
<th>Price</th>
<th>Quality</th>
<th>-1.0</th>
<th>-.8</th>
<th>-.6</th>
<th>-.4</th>
<th>-.2</th>
<th>0</th>
<th>+.2</th>
<th>+.4</th>
<th>+.6</th>
<th>+.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>-.8</td>
<td>.230</td>
<td>.180</td>
<td>.131</td>
<td>.087</td>
<td>.058</td>
<td>.040</td>
<td>.026</td>
<td>.017</td>
<td>.009</td>
<td>.004</td>
<td></td>
</tr>
<tr>
<td>-.6</td>
<td>.416</td>
<td>.320</td>
<td>.228</td>
<td>.146</td>
<td>.093</td>
<td>.059</td>
<td>.036</td>
<td>.023</td>
<td>.011</td>
<td>.004</td>
<td></td>
</tr>
<tr>
<td>-.4</td>
<td>.634</td>
<td>.488</td>
<td>.339</td>
<td>.212</td>
<td>.129</td>
<td>.080</td>
<td>.047</td>
<td>.028</td>
<td>.013</td>
<td>.004</td>
<td></td>
</tr>
<tr>
<td>-.2</td>
<td>.730</td>
<td>.556</td>
<td>.378</td>
<td>.230</td>
<td>.140</td>
<td>.086</td>
<td>.051</td>
<td>.031</td>
<td>.013</td>
<td>.004</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>.852</td>
<td>.642</td>
<td>.433</td>
<td>.256</td>
<td>.152</td>
<td>.094</td>
<td>.055</td>
<td>.031</td>
<td>.013</td>
<td>.004</td>
<td></td>
</tr>
<tr>
<td>+.2</td>
<td>.913</td>
<td>.683</td>
<td>.448</td>
<td>.259</td>
<td>.154</td>
<td>.095</td>
<td>.056</td>
<td>.031</td>
<td>.013</td>
<td>.004</td>
<td></td>
</tr>
<tr>
<td>+.4</td>
<td>.973</td>
<td>.721</td>
<td>.448</td>
<td>.262</td>
<td>.156</td>
<td>.096</td>
<td>.056</td>
<td>.031</td>
<td>.013</td>
<td>.004</td>
<td></td>
</tr>
<tr>
<td>+.6</td>
<td>.986</td>
<td>.727</td>
<td>.467</td>
<td>.262</td>
<td>.156</td>
<td>.096</td>
<td>.056</td>
<td>.031</td>
<td>.013</td>
<td>.004</td>
<td></td>
</tr>
<tr>
<td>+.8</td>
<td>1.000</td>
<td>.734</td>
<td>.467</td>
<td>.262</td>
<td>.156</td>
<td>.096</td>
<td>.056</td>
<td>.031</td>
<td>.013</td>
<td>.004</td>
<td></td>
</tr>
</tbody>
</table>

---

8
$q = 0$

$q = -0.2$

$q = -0.4$

$q = -0.6$

$q = -0.8$

**FIGURE 4. SALES POTENTIAL VS. PRICE WITH QUALITY CONSTANT**
FIGURE 5. SALES POTENTIAL VS. QUALITY WITH PRICE CONSTANT
the only element of product cost which would vary would be the
cost of quality. Next it was assumed that one-half of all vari-
able product manufacturing costs was expended to produce some-
thing better than minimum quality. The latter assumption gives
the convenient situation of percentage price changes required
to maintain constant margin being equal to one-half the per-
centage quality changes. Using this constant margin criterion,
the family of curves in Figure 6 were determined. Several
series of price-quality combinations with the increments be-
tween prices of adjacent combinations one-half the increment
in quality were selected. The several curves in the family
result from choosing different combinations of price and qual-
ity as starting points of a series.

Market Conditions at the Maximum Profit Position

It is interesting to note in Figure 6 that the maximum
sales and thus maximum profits occur at a nearly constant
quality level of approximately -.4. Referring back to Fig-
ure 3 reveals that, at this quality level, four market seg-
ments are prepared to buy at their maximum level from the
standpoint of quality. In these four segments are the three
highest $\alpha_t$ values and one $\alpha_t$ at mid-range. In other words,
these people can afford to pay for higher quality and they
are more quality conscious. In terms of market coverage, the
four segments include 23 percent of the household spending
money available; at the price-quality combinations for maxi-
mum sales they account for approximately 50 percent of total
FIGURE 6. SALES POTENTIAL VS. QUALITY WITH MARGIN CONSTANT
sales. Even at the low price level of -.6 with a quality level of -.4 these same four customer segments will limit their purchases to 70 percent of available funds because of price, while the remaining customers limit themselves to 23 percent on the average.

From the above observations it appears that in this example the maximum profits position with constant profit margin is characterized as follows:

1. Quality is sufficiently good to convince the most quality-discerning customers to buy at their full ability except as limited by price. (In this example these customers spend 23 percent of the market money available.)

2. The group of customers that are fully satisfied with quality represent approximately 50 percent of the total sales potential. (Thus, in this example 50 percent of sales will come from 23 percent of the market dollars available.)

3. It follows that a significant portion of the market (77 percent in this model) will be sufficiently unimpressed with quality to limit buying to a low fraction of their available funds.

The Interpretation of Sales Potential

At this point, further discussion of the interpretation of Figure 3 seems in order. At first, it may seem paradoxical for the most quality-conscious customers to reach their maximum
sales potential at a lower quality level than any of the others. This simply means that the quality sensitive customers detect smaller quality improvements than others and respond sooner with greater purchases. This phenomenon is dependent upon the assumed shape of $f_{2t}(q)$. Shapes other than the one noted are possible, but this one has some justification. Critical customers may be less satisfied with quality than others; they may merely recognize the quality improvement over other products sooner than other customers. A practical illustration would be the housewives critical of floor wax quality who buy the best wax consistently and at the same time are the chief sources of complaints on quality. Less critical customers will complain less about quality and will be less consistent in buying the best brand. These conditions, if they hold in practice, are important in manufacturing for they imply that, if quality is improved as a result of complaints by the critical customers, any resulting new business must come primarily from less critical customers. Furthermore, the new business stimulated may be so small that profits actually decrease.

Throughout this chapter the discussion has proceeded on the assumption that the product and market already exist and that all external factors remain constant. There has been no consideration given to competition; the model is closer to a monopoly situation than any other type of market. Chapter VI is devoted to extending this model to competitive situations.
F. SUMMARY

Consumers can be identified by several characteristics such as income, family size or residence. Experience has given indications of the buying habits associated with these identifying characteristics. Once market composition is determined, estimates can be made of sales potential from the many consumer segments which, when combined, give the total market sales potential. Assembling a market estimate from its parts in this fashion can be done with some success, whereas an attempt to predict total market directly might be nearly hopeless.

The market behavior at the maximum profit position was studied using this model developed by market segments. In the example, the maximum profits position for a firm operating with constant percent margin occurs at a nearly constant quality level regardless of price. The quality level associated with maximum profits results in approximately 23 percent of the market available limiting their purchases only on the basis of price. This 23 percent of the available market consumes approximately one-half the total sales. Somewhat paradoxically, the 23 percent minority most willing to buy because they recognize a quality advantage, may well be most critical of whatever quality limitations remain. A manufacturer who, in this situation, responds to the critical customer's demands for quality may be disappointed by a small sales gain if he improves quality. Most of the gains realized must come from the
more quality indifferent consumers who have previously represented a low potential sales and who will continue to respond slowly to quality improvements.
Chapter VI

A COMPETITIVE MODEL

In Chapters IV and V, models were used to study market conditions at the maximum profit position without considering the effects of competition. Using the segmented market model of Chapter V, several products can be assumed simultaneously in a competitive model. Since competitive position is strongly affected by price, two pricing policies will be considered.

A. CALCULATING MARKET SHARE

As products enter or leave a competitive market they will produce different changes in sales in the different market segments. For this reason, the competitive position of each product will be determined independently for each market segment and then combined to give the total competitive position. In this manner, sales are divided among competitors on the basis of their individual market segment sales potential.

It is assumed that the combined sales potential of all competitors in any market segment is no greater than the largest sales potential for any single competitor. In other words, additional products with less appealing price and quality will not increase the total market but will share part of the existing market.

Eight competitive situations were explored, each having
two existing competitors and one new product. Using $s_{cl}$, $s_{c2}$ and $s_n$ as the market segment sales potential for the first competitor, second competitor and new product respectively, the calculations of market share for the new product, as a fraction of all sales in the market segment, were made as follows:

a) when $s_n < s_{c2} \leq s_{cl}$:

$$\text{Market Share} = s_n \left( \frac{s_n}{s_n + s_{cl} + s_{c2}} \right)$$  \hspace{1cm} (1a)

b) when $s_{c2} < s_n < s_{cl}$:

$$\text{Market Share} = \left( s_n - s_{c2} \right) \frac{s_n}{s_n + s_{cl}} + s_{c2} \left( \frac{s_n}{s_n + s_{cl} + s_{c2}} \right)$$  \hspace{1cm} (1b)

c) when $s_{c2} < s_{cl} < s_n$:

$$\text{Market Share} = \left( s_n - s_{cl} \right) + \left( s_{cl} - s_{c2} \right) \frac{s_n}{s_n + s_{cl}} + s_{c2} \left( \frac{s_n}{s_n + s_{cl} + s_{c2}} \right)$$  \hspace{1cm} (1c)

($s_{cl}$ and $s_{c2}$ can be interchanged in each of the above three cases, values for $s$'s are given by equation (2) of Chapter V)

The above equations were chosen to let a product share
the market in proportion to its sales potential up to the level of its sales potential. Above this level the remaining products share the market in proportion to their sales potential. These equations thus recognize sales potential as an indicator of relative market share, and in addition they allow a product with the highest sales potential to create an increase in the market which is not shared with competitors.

Since equations (1a), (1b), and (1c) are applied for each market segment, a competitive situation of three products requires 12 market share determinations per product, or a total of 36 determinations. Adding the three market share values for each market segment will total to the value of the largest potential sales of the three products. Thus, market share is in terms of potential sales.

Total sales are obtained for each product by a similar calculation to that shown in equation (5) of Chapter V. The market share values for each market segment are multiplied by the fraction of total U.S. spending for household operation available in that segment; these products are then summed for the 12 segments to give total sales.

Thus:

\[
S = \sum_{t} \text{Market Share}_t \times H_t
\]

(2)
B. CHOICE OF COMPETITOR SITUATIONS

The eight competitive situations studied fall into three groups as follows:

1. Trials 1, 2 and 3
   a. All products at 33 percent margin
   b. First competitor with a deluxe quality product superior to all competition
   c. Second competitor with quality at the maximum profit position for a monopoly

2. Trials 4 and 5
   a. All products at 33 percent margin
   b. First competitor with quality at the maximum profit position for a monopoly
   c. Second competitor with a better than average quality product (halfway between the maximum profit position and the deluxe quality competitor of group 1 above)

3. Trials 6, 7 and 8
   a. Two competitor products at 33 percent margin and a new product at 17 percent margin (obtained by reducing price 20 percent from the 33 percent margin level)
   b. Competitor products with quality the same as in group 2 above
New products were introduced with the following quality characteristics:

**Trial**

1. Quality midway between the two competitors. A better than average quality, high priced product where none previously existed, attempting to appeal to customers wanting better quality but not willing to pay the top price.

2. Quality below the lower quality competitor. A goal of reaching customers who will accept lower quality at a lower price.

3. Quality the same as the lower quality competitor. An attempt to share the majority of the existing market by direct competition.

4. Quality below the lower quality competitor. Similar to No. 2 with different competition.

5. Quality the same as the lower quality competitor. Similar to No. 3 with different competition.

6. Quality the same as the higher quality competitor. A high quality product at the standard price.

7. Quality the same as the lower quality competitor. A standard quality product at an economy price.

8. Quality higher than the higher quality competitor. A very high quality product priced to compete with existing high quality competition.

Using equation (2), total sales were calculated for each
of the three products in each of the eight competitive situations. Profits were calculated from the sales figures by multiplying percent margin times sales. Results of these calculations are shown in Table VIII. Although companies might make their marketing decisions on the basis of market share or sales, profits are a more rational criterion for most cases. This study will be discussed only in terms of profits as a criterion for decision. Total profits by products are shown graphically in Figure 7 using the data given in rows 16, 17 and 18 of Table VIII. The tabulation of profits by product permits viewing the new product as being that of one of the existing companies or that of a new competitor with possibly quite different views on total profitability to the introducer.

C. INTERPRETATION OF RESULTS

The competitive model suggests that, for the market as modeled here, the most profitable quality level for the new product by itself is close to that for a monopoly situation. A new product as in Trial 3 surpasses Trials 1 and 2; Trial 5 surpasses Trial 4; and Trial 7 surpasses Trials 6 and 8.

It is clear that the sales responses to quality and price used in this model give favorable results from reducing the profit margin to 17 percent. A manufacturer wishing to enter an existing market having two competitors can increase profits 13 percent by reducing margin. This comparison exists between Trials 5 and 7. New problems would no doubt accompany the profit increase. For one, the over twofold increase in
### TABLE VIII
MARKET PERFORMANCE WITH A COMPETITIVE MODEL

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<td>.5</td>
<td>.6</td>
<td>.7</td>
<td>.8</td>
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<tr>
<td>2. First Competitor Price</td>
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<td>0</td>
<td>.6</td>
<td>.6</td>
<td>.6</td>
<td>.6</td>
<td>.6</td>
<td>.6</td>
</tr>
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<td>3. First Competitor Quality</td>
<td>.4</td>
<td>.4</td>
<td>.4</td>
<td>.4</td>
<td>.4</td>
<td>.4</td>
<td>.4</td>
<td>.4</td>
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<td>4. Second Competitor Price</td>
<td>-.4</td>
<td>-.4</td>
<td>-.4</td>
<td>-.4</td>
<td>-.4</td>
<td>-.4</td>
<td>-.4</td>
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<td>5. Second Competitor Quality</td>
<td>-.4</td>
<td>-.4</td>
<td>-.4</td>
<td>0</td>
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<td>0</td>
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<td>6. New Product Price</td>
<td>-.2</td>
<td>-.6</td>
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<td>-.6</td>
<td>-.6</td>
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<td>7. New Product Quality</td>
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<td>-.8</td>
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<td>-.8</td>
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<td>8. Margin of New Product</td>
<td>.33%</td>
<td>.33%</td>
<td>.33%</td>
<td>.33%</td>
<td>.33%</td>
<td>.17%</td>
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<td>9. Sales of First Competitor</td>
<td>.026</td>
<td>.033</td>
<td>.022</td>
<td>.190</td>
<td>.134</td>
<td>.122</td>
<td>.107</td>
<td>.187</td>
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<tr>
<td>10. Sales of Second Competitor</td>
<td>.134</td>
<td>.146</td>
<td>.095</td>
<td>.115</td>
<td>.088</td>
<td>.077</td>
<td>.080</td>
<td>.084</td>
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<tr>
<td>11. Sales of New Product</td>
<td>.063</td>
<td>.052</td>
<td>.095</td>
<td>.055</td>
<td>.134</td>
<td>.234</td>
<td>.301</td>
<td>.091</td>
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<td>12. Total Sales with New Product</td>
<td>.223</td>
<td>.231</td>
<td>.212</td>
<td>.360</td>
<td>.356</td>
<td>.433</td>
<td>.488</td>
<td>.362</td>
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<td>14. New Market</td>
<td>.011</td>
<td>.019</td>
<td>0</td>
<td>.004</td>
<td>0</td>
<td>.077</td>
<td>.132</td>
<td>.006</td>
</tr>
<tr>
<td>15. Market Held by New Product</td>
<td>.28%</td>
<td>.23%</td>
<td>.45%</td>
<td>.15%</td>
<td>.38%</td>
<td>.54%</td>
<td>.62%</td>
<td>.25%</td>
</tr>
<tr>
<td>16. Profits of First Competitor</td>
<td>.009</td>
<td>.011</td>
<td>.007</td>
<td>.063</td>
<td>.045</td>
<td>.041</td>
<td>.036</td>
<td>.062</td>
</tr>
<tr>
<td>17. Profits of Second Competitor</td>
<td>.045</td>
<td>.049</td>
<td>.032</td>
<td>.038</td>
<td>.029</td>
<td>.026</td>
<td>.027</td>
<td>.028</td>
</tr>
<tr>
<td>18. Profits of New Product</td>
<td>.021</td>
<td>.017</td>
<td>.032</td>
<td>.018</td>
<td>.045</td>
<td>.040</td>
<td>.051</td>
<td>.015</td>
</tr>
<tr>
<td>19. Total Profits, All Products</td>
<td>.075</td>
<td>.077</td>
<td>.071</td>
<td>.119</td>
<td>.117</td>
<td>.107</td>
<td>.114</td>
<td>.105</td>
</tr>
</tbody>
</table>
$C_1$ - First Competition
$C_2$ - Second Competition
$N$ - New Product

**FIGURE 7.** PRODUCT PROFITS IN A COMPETITIVE MODEL
sales required to get the higher profits might require considerable capital outlay for manufacturing and distribution. The model is only measuring the effects of manufacturing costs, thereby ignoring capital costs. A second problem associated with reducing margin is the action likely to be taken by competitors. In many cases the competitors would probably reduce their margins in order to price competitively. Such price competition would force the relative market position of the new product from a situation like Trial 7 toward Trial 5. The three competitors would prefer not to reduce prices below the point where increased sales compensate for decreased margin; therefore, price competition could benefit customers by lower prices and might benefit manufacturers by moving them closer to the most profitable price. The margin reduction to 17 percent shown in Trial 7 gave a 37 percent increase in the total market served by all three products combined. Subsequent price reduction by the competitors would increase sales by a somewhat smaller amount; only the higher quality product would be effective in increasing sales, the lower quality competitor would share existing volume with the new product.

Another possibility shown by Trial 7 is that a single manufacturer with two existing products would enhance the total profitability of all products combined by introducing a product with quality below his lower quality product. This product will increase profits by a small amount by cultivating a new market. The gain in profits may well be offset by increased capital costs associated with introducing a new prod-
uct. Trials 2 and 4 illustrate such a situation in which new market is stimulated and total profits for all products maximized. Following the approach of a new lower quality product may offer the added advantage of discouraging other manufacturers from entering the market at the lower quality level.

Still another point of view is that of a company with two products that wants to design their products for maximum protection from future market invasion by others. Profits of the two competitors in Trials 1, 2 and 3 averaged .051 compared to .079 for Trials 4 through 8. This suggests that the closer spacing of product quality shown in Trials 4 through 8 is an advantage in terms of protection against competition.

D. SUMMARY

The Chapter V model of a segmented market is useful as a basis for a competitive model. Market distribution among two existing competitors and a new product were studied under eight trial conditions. Resulting sales for each product are determined by calculating the sales distribution for each market segment on the basis of the potential sales for each product.

Results are limited by the conditions chosen for the eight trials; however, a few suggested findings are as follows:

1. Product quality for maximum profits on the new product by itself was close to that of the monopoly model of Chapter V.
2. A company planning to enter a market containing two existing products (at 33 percent margin) did well by matching the quality which gave maximum profits for a monopoly and cutting margin.

3. A company with two existing products intending to bring out a third product maximized profits by choosing a quality level below the existing dominant product, and pricing at the same margin. This procedure has the advantage that it cultivates a new market; however, the gain in total profits was slight.

Although the above statements are provocative, they are merely indications from the model and could bear substantiation by more trials. There is an assumption that all things other than quality and price remain constant. In a dynamic market this will normally not be the case. However, results such as those found here can serve as helpful indications of the effects produced by the actions simulated.
Chapter VII

TESTING WITH COMPANY DATA

It was stated earlier that the value of a model can be measured by how well it represents real situations. Also, there was the suggestion that data will rarely exist ready-made for models having quality, price and sales interrelationships. In the presence of this paradoxical situation an attempt will be made to test the models against a real manufacturing operation, but admittedly the available data are limited.

Manufacturing data were examined for a consumer product group having national distribution. The information included sales, quality measurements, prices and costs for three products from 1950 through 1962. During this discussion the data will be coded, and no reference will be made to the manufacturer or the products in order to protect the privacy of the information.

A. SALES RESPONSE ESTIMATES

Even with limited data there may be a valuable testing of the concepts on which the models are founded. The manufacturing data obtained were extracted from historical information that happened to exist, having been generated for other purposes. Data for the three products examined are shown in Table IX and Figure 8.
### TABLE IX

MANUFACTURING DATA FOR PRODUCTS A, B AND C

<table>
<thead>
<tr>
<th>Year</th>
<th>Product A</th>
<th>Product B</th>
<th>Product C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>$0 \times 10^3$</td>
<td>$0 \times 10^3$</td>
<td>$22 \times 10^3$</td>
</tr>
<tr>
<td>1951</td>
<td>4</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>1952</td>
<td>13</td>
<td>0</td>
<td>34</td>
</tr>
<tr>
<td>1953</td>
<td>20</td>
<td>0</td>
<td>41</td>
</tr>
<tr>
<td>1954</td>
<td>23</td>
<td>0</td>
<td>42</td>
</tr>
<tr>
<td>1955</td>
<td>19</td>
<td>0</td>
<td>43</td>
</tr>
<tr>
<td>1956</td>
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<tr>
<td>1957</td>
<td>31</td>
<td>0</td>
<td>39</td>
</tr>
<tr>
<td>1958</td>
<td>32</td>
<td>0</td>
<td>34</td>
</tr>
<tr>
<td>1959</td>
<td>36</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>1960</td>
<td>53</td>
<td>44</td>
<td>7</td>
</tr>
<tr>
<td>1961</td>
<td><strong>63</strong></td>
<td><strong>53</strong></td>
<td>0</td>
</tr>
<tr>
<td>1962</td>
<td>72</td>
<td>57</td>
<td>0</td>
</tr>
</tbody>
</table>

Quality-- measured on an arbitrary scale:
- 1950-52: 21
- 1952-58: 74
- 1958-62: 95

**Price in Dollars**
- 1958-62: $68
- 1958-62: $53
- 1958-62: $83

**Cost (m + q) in Dollars**
- 1958-62: $30
- 1958-62: $24
- 1958-62: $37

Sales data for Product A shows a noticeable increase beginning in 1952, another in 1955 and a third sharp increase in 1958. Each increase in sales follows closely after a product change to improve product quality. Product C shows a sharp drop in sales beginning in 1957 and ending in discontinuance of the product in 1961.

Product A has sufficient sales and quality data to provide some basis for comparison with the company profit model. Prices of Product A were nearly constant from 1950 through 1962. The observed increases in sales following quality...
FIGURE 8. ANNUAL SALES FOR PRODUCTS A, B AND C
improvements support a basic postulate of the models that sales and profits are influenced by product quality. If we were to attribute all the sales growth of Product A to quality improvements, an estimate of sales response to quality \( \frac{dS}{dQ} \) is given by \( \frac{\Delta S}{\Delta Q} \). In this case \( Q \) is the value of the arbitrary quality assessments. Estimating sales response in this way gives a plausible upper limit to the values of \( \frac{dS}{dQ} \) can have.

Two calculations of \( \frac{\Delta S}{\Delta Q} \) can be made using sales for the most recent year a given quality level existed as follows:

1) 1952 to 1958: \( \frac{\Delta S}{\Delta Q} = \frac{(32 - 13) \times 10^3}{74 - 21} = \frac{19 \times 10^3}{53} = .36 \times 10^3 \)

2) 1958 to 1962: \( \frac{\Delta S}{\Delta Q} = \frac{(72 - 32) \times 10^3}{95 - 74} = \frac{40 \times 10^3}{21} = 1.9 \times 10^3 \)

Data are not adequate to relate values of \( Q \) to the cost of quality \( q \) used in the model. It is believed that the quality improvement shown in the second case above came from a greater increase in \( q \) than the first case. Therefore, as used in the company profit model, the relative \( \frac{dS}{dq} \) values in the two cases may be quite different from the relative \( \frac{dS}{dQ} \) values shown here. For instance, the two values of \( \frac{dS}{dq} \) may be more nearly equal.

This discussion can be carried another step to choose future action. Suppose there are means available to increase the quality of Product A to 105 and we know the associated costs. We can then determine whether the move would be advisable under the condition that the sales response to quality continues at \( \frac{dS}{dQ} = 1.9 \times 10^3 \). The sales increase resulting from a quality increase to 105 is then estimated as follows:
\[ S = \Delta Q \times 1.9 \times 10^3 = (105 - 95) \times 1.9 \times 10^3 = 19 \times 10^3 \]

If it is estimated that the quality increase would increase the unit cost from $30 to $36 Gross Profits at the new position would then become:

\[ \text{Gross Profits} = (72 + 19) \times 10^3 \times (68 - 36) = $2912 \times 10^3 \]

compared to Gross Profits at the current position:

\[ \text{Gross Profits} = 72 \times 10^3 \times (68 - 30) = $2736 \times 10^3 \]

Thus Gross Profits might be increased seven percent by the quality improvement. Further calculations would show that the unit cost could be increased as high as $38 and still break even on Gross Profits. In view of the fact that 1.9 x 10^3 is the upper limit for the true sales response to quality, the company should probably not make the additional quality improvement for only a seven percent increase in Gross Profits. Other factors which might support this decision are the inaccuracies of the predictions and possible detrimental side effects on cost or quality. All these risks must be considered by management in making the decision.

B. INTERNAL COMPETITION

Products A, B and C are competitive with one another. This competition offers the opportunity to compare in a general way company results with the phenomena which would be predicted by a competitive model like that of Chapter VI. Three things
began to happen in 1958:

1. The quality of Product A was improved.
2. Product B was introduced.
3. Product C began to show signs of losing sales and quality was declining.

In the competitive model, the increase in quality of Product A from 74 to 95 compared to C's quality of 42, coupled with A's lower price of 68 vs. 83 for C would take sales away from C in all market segments. New sales for A would also result from the quality increase. Furthermore, the introduction of B at a slightly lower price and quality than A would give it a good market share in certain segments and possibly create new sales in price conscious segments.

These changes are what happened in the real situation. By 1962 Product B had nearly the volume of Product A and Product C was discontinued. Since Product A initially had a lower price than Product C, the quality improvement made in 1958 was enough to spell the end of Product C.

Company Gross Profits for each product in 1958 and 1962 were as follows:

<table>
<thead>
<tr>
<th></th>
<th>1958</th>
<th>1962</th>
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</thead>
<tbody>
<tr>
<td>Product A</td>
<td>$1216 \times 10^3$</td>
<td>$2736 \times 10^3$</td>
</tr>
<tr>
<td>Product B</td>
<td>--</td>
<td>1653</td>
</tr>
<tr>
<td>Product C</td>
<td>1564</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>$2780</td>
<td>$4389</td>
</tr>
</tbody>
</table>

It would appear from the above table that the company took action in regard to product quality which tended to increase
profits. In addition, as mentioned earlier, the action produced results which are what would be expected from a segmented market model like that of Chapter VI.

C. DEVELOPMENT COSTS FOR QUALITY IMPROVEMENTS

Examination of the company data used herein raises a question with regard to measuring quality cost. In the Company Profit Model of Chapter IV, quality was treated as a function which could be controlled by the cost of manufacture. In many cases there is also a development cost required to bring about a quality improvement. For example, the quality improvements in Product A made in 1952, 1955 and 1958 undoubtedly required substantial development costs. There are at least three methods for handling these costs. They can be considered as:

1. An investment for future pay-back from profits
2. A cost distributed over future production units
3. General development costs of the company not specifically related to pay-back or profits.

The usual method in practice is either No. 1 or No. 3 above. Development funds are normally appropriated on the basis of economic justification based on anticipated pay-back; however, once spent, development costs are not related to production operating costs. Similarly, research costs for new products are not directly associated with unit costs or profits of subsequent production.

After considering the above points, the rationale of the model appears quite acceptable. Product quality has an asso-
ciated cost for each unit over which management has some degree of control. Since this cost continues for the life of the product manufacturing system, it is important to choose its optimum level. Development costs, on the other hand, are incurred but once; they can therefore be treated as investments using a suitable return-on-investment criteria.

D. SUMMARY

The value of the models developed in this study is unknown unless they can be tested against actual situations. Without designing such test situations, available data are unlikely to be well suited for the task.

Consumer product manufacturing data were examined for one company. Three products were studied; one strong growth product A, a new product B, and a declining product C. It was observed that sales of Product A tended to increase with quality improvements; however, this was difficult to express in the Company Profit Model since quality measurements were not in terms of unit quality cost as used in the model. Using the quality assessment data available, estimates were made of sales response to quality. Then assuming this response and estimated costs of further quality improvements, it was shown that a maximum of 7% increase in profits might be possible with further quality improvements in Product A. Considering the marginal nature of this increase, it is suggested that Product A may be near the optimum quality position.

The three company products provide an internal competi-
tion situation which can be compared to the competitive model. Product C was driven from the market by price and quality competition from Products A and B. The decline of Product C resulted from company decisions to improve Product A and to introduce Product B with quality and price slightly lower than Product A. These product changes produced results in agreement with the postulates of the competitive model.

In short, there is some basis to believe that the models contain important features found in actual practice; furthermore, if the estimates from the model are reasonably correct, the company made sound quality and price decisions.
Chapter VIII

APPRAISAL

A. THE COMPANY PROFIT MODEL

Applications

A series of statements to guide a manufacturer were suggested by the company profit model of Chapter IV. Conceivably, with present knowledge, these statements are of little use to a manufacturer of consumer goods; on the other hand they need not remain so indefinitely. If a manufacturer watches for conflicting or confirming evidence relative to the model, he opens possibilities for substantial benefits. Feedback from the model will encourage the use of estimates of sales response or demand together with the marginal cost and revenue concepts.

Manufacturers have a need for quantitative means of determining their optimum product quality position. Competitive forces place increasing pressures on manufacturers to operate at optimum efficiency. Possibly the results of the company profit model can become useful to a manufacturer if more can be learned about their application.

The most serious limitation to application of the models is the lack of methods for obtaining sales response to price and quality. Existing data in most companies are probably confounded with other variables such as increasing dis-
posable income or consumer awareness of the product. Experiments in the market are difficult and costly. In spite of these discouraging notes, there is still good reason to be optimistic that progress can be made here as in other similar model applications. Perhaps the best way to begin is to apply what is currently available in the hope of making improvements with experience.

Following the above suggestions, the first step might be to choose the pricing policy for the product being studied. This will probably require approximations, for the pricing activity usually includes a variety of considerations. Three pricing policies and their associated maximum profits position descriptions as derived in Chapter IV are as follows:

<table>
<thead>
<tr>
<th>Price Constant</th>
<th>Price Changes Equal Quality Cost Changes</th>
<th>Price Independent of Quality Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{marginal cost} = \frac{\text{marginal revenue}}{(\text{from increased quality})} )</td>
<td>( \text{sales gain from quality increase} = \text{sales loss from associated price increase} )</td>
<td>( \text{marginal cost} = \frac{\text{marginal revenue}}{(\text{from increased quality})} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{sales gain from quality increase} = \text{sales loss from associated price increase} )</td>
</tr>
</tbody>
</table>

In order to make use of the above maximum profit position descriptions, it is necessary to estimate the sales
responses and marginal revenues and costs. With this information, a manufacturer could make gradual changes to move in the direction required to satisfy the above identities. Any changes should be made in small increments with a careful eye toward the results. If results tend to support the model criterion of maximizing profits, further changes can be made. Such experimental adjustments should be carefully designed to provide useful data with suitable control conditions. For instance, a price or quality change could be introduced in a specific geographic location while all other conditions, such as advertising and customer service, remain constant in all market areas. Sales and profits can then be compared between the test area and other markets with the inference that any differences are due to the price or quality change in the test area.

Limitations

There are several limitations to the company profit model as follows:

1. It idealistically assumes sales and price as functions of a few variables.
2. It assumes that factors other than quality are held constant.
3. Competitor activity and reaction is ignored.
4. It assumes that the sales and price functions are differentiable.
5. It ignores capital costs.
Obviously this is a highly idealized model; however, idealized models are often useful. For instance, many of the basic laws of physics assume idealized and unattainable conditions such as a perfect vacuum or frictionless motion. The above limitations can best be judged after the model has been tested with practical situations. If practical tests fail to fit the model, changes can be made to include other variables, competitor activity, etc.

B. THE SEGMENTED MARKET AND COMPETITIVE MODELS

Applications

In instances where the product market is well defined, the segmented market model offers a way to construct inputs to the company profit model. In addition to providing relatively simple means for representing market behavior, the segmented market model is well suited to simulation of proposed products in order to predict results. Whereas the company profit model treats sales responses for the aggregate market, the segmented market model uses sales responses at the most elementary level of the market segment breakdown. There are probably many instances where suitable sales response estimates can be made for the carefully specified market segments, while it would be absurd to try to estimate the market response as a whole.

Once it is determined that market segment definitions with suitable associated sales responses and market dollar spending can be obtained, useful application of the segmented
market model can begin. All remaining work consists of routine calculations. From these models a manufacturer can determine the following relative to his maximum profit position:

1. The quality level at which profits will be maximum (given a pricing policy).
2. The degree of satisfaction with product quality for each market segment (given by the potential sales values).
3. The distribution of sales among market segments.
4. Estimates of the most promising areas for future sales growth.
5. Estimates of market share and profits in competitive situations.
6. Results to be expected from competitive strategy alternatives.

There are a number of descriptive statements relevant the maximum profit position which can be made for the particular segmented market and competitive models studied here:

1. In a monopoly situation the quality level associated with maximum profits appears to be the same regardless of the profit margin used (assuming profit margin remains fixed once chosen).
2. Only a small minority of the customers may be sufficiently sensitive to quality to buy the product exclusively. These customers, however, may account for the majority of sales and complaints.
3. A manufacturer introducing a new product into a
competitive market can increase profits by cutting margin relative to the competitors (assuming the competitors in the market do not try to match the price cut).

4. A manufacturer with existing products should enter subsequent products at new quality levels to develop new markets.

5. A manufacturer can best protect his multiple product line against competition by having quality levels spaced at reasonable intervals around the maximum profit quality level but not widely dispersed.

Limitations

In addition to the idealized nature of the segmented market model, there are limitations such as:

1. Numerous calculations must be made when thorough market segmentation is attempted.

2. It is awkward to use the model if constant profit margins are not assumed.

3. Solutions are not general. They may apply only to the circumstances simulated.

4. Complexity increases rapidly if additional variables are added. Use of computers might help in this case and those above.

It is suggested that these models, although limited, are probably more informative than the company profit model. They have the inherent ease of self-examination by repeated
trials with different assumed conditions to test sensitivity to assumptions.

C. GENERAL APPROACH OF THIS STUDY

The study undertaken herein had the primary purpose of learning about the possible uses of models for studying the effect of product quality on company profits. It was recognized that in an exploratory study such as this there was little chance of producing highly useful and immediately applicable management decision tools.

The original objective has been realized. There is evidence that models can be useful in defining optimum product quality; moreover, there are some specific inferences from the models which have the character of basic principles. Further work seems justified to test these inferences and to venture closer to the area of application to a real situation.

While the decisions being examined were in marketing areas, this study was undertaken primarily from a manufacturing point of view. If product quality is to be adjusted, manufacturing operations must make the change. It may involve development programs or simply adjustments to the manufacturing process. Thus, a marketing problem involving product quality is equally a manufacturing problem. This dual organizational responsibility for product quality level should not be a serious deterrent to the successful use of models. Undoubtedly the most serious hindrance for some time to come will be the lack of reliable estimates of market response to quality and
price. Manufacturing decisions based on these models will have associated economic risks. The task remains to identify the risks and reduce them to acceptable proportions by refinements in the models as needed.

In its most useful state, a model such as discussed here can aid a manufacturer in determining his optimum product quality. This knowledge should make it possible to maximize profits and take the best competitive strategy. The model will not make management decisions, but it can serve as a tool in the decision process. Furthermore the model is well suited to the dynamic nature of markets by giving an easy way of continually assessing the position of the company. These suggestions of the potential practical value of the models are, to some extent, substantiated by the testing with company data performed in Chapter VII.
BIBLIOGRAPHY

Books


Periodicals


