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This paper proves that the product life cycle of a new consumer durable goods product can be simulated with reasonable accuracy assuming various causal marketing conditions. Major elements of the model development are discussed as well as the validity tests conducted. Strategic and operational uses of the model are also discussed.

MODELING THE PRODUCT LIFE CYCLE FOR CONSUMER DURABLES

Introduction

THIS paper will discuss the purpose and usage of the Product Life Cycle (PLC) relative to consumer durable goods industries. It will demonstrate a method of constructing a model that will effectively predict the industry volumes of a newly introduced product through each stage of its life, based on various marketing assumptions. The two-phase process used to validate the model will also be discussed.

Since there are many external influences that can impact a new product life cycle, several examples will be presented along with illustrations of possible methods of dealing with such exogenous variables. Some observations on how the model has been used for planning purposes within the electric housewares industry will also be discussed along with other possible strategic implications within the consumer products industries.

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The PLC is the basic fuel that supplies the lifeblood of the electric housewares industry. Contrary to Dhalla and Yuspeh (1976), the PLC is alive and well in the electric housewares industry. While the housewares industry predates many consumer hard goods categories,[1] it has constantly been characterized by product innovation and development of new[2] product categories. Contemporary examples of new industry categories include the slow cooker, smoke alarm, food processor, and curling iron. New housewares product introductions have averaged about three per year. A study of the saturation curves for 10 of these new electric housewares product introductions (Figure 1) indicates that no two are the same.

The reasons for this diversity include differences in price level, rate of price erosion, degree of consumer need/want, and the degree of aggressiveness in the marketplace. Because there is an almost infinite number of possible values for each of these

[1] The first electric iron was patented in 1882.
[2] The authors recognize that the term "new" is subject to broad interpretation.

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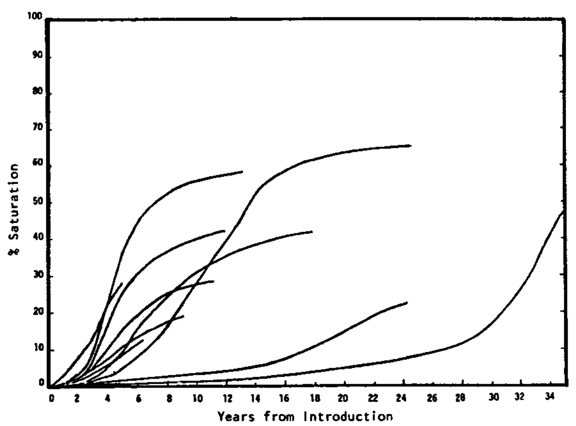
FIGURE 1
Electric Housewares Saturation Curves—10 Typical Examples



Source: Merchandising, January 1960 through March 1980, passim.

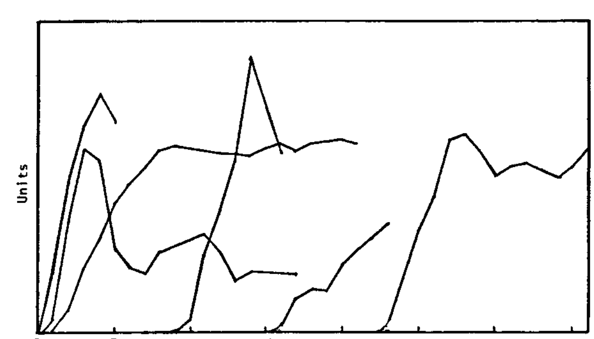
variables over time, it is readily understandable how the possible combinations become enormous and create such diverse saturation curves that no two are likely to be the same or even similar. As this paper will show, the shape of individual PLC's is directly related to saturation. It therefore follows that each PLC would have its own individualistic shape as illustrated in Figure 2. This explains some of the reasons students of the PLC have encountered considerable difficulties and disagreements attempting to catalog and define similar PLC patterns. Even discussions as to what constitutes the typical PLC shape are not uncommon. For example, Weinhold-Stunzi (1964) has noted that a camel-back cycle often exists, while Nielsen (1967) referred to this as a primary cycle/recycle pattern. When certain combinations of these causal influences are present, the shape of the particular PLC will exhibit certain characteristics with amazing consistency. Many of these causal influences are relatively independent of each other. That is why such diverse PLC shapes as the camel-back can be detected with nearly the same frequency as any other shape.

Purpose

Development of a PLC model was undertaken primaily to provide a tool for evaluating potential success (or failure) of new product development projects generated within the housewares industry but not for studying substitution effects. Inherent in any new product development processes are significant investments of financial and human resources. These represent the risks of the project. The rewards relate to income over time. The model provides a quantitative basis upon which the risk/reward ratios may be estimated. In a business where the risk of failure on new product introductions has historically been about 50–60% depending upon how one defines failure, any tool for decreasing the probability of failure would be most welcome.

Perhaps equally important was the need to be able to predict the timing and magnitude of turning points of a successful product introduction. For example, the PLC model was used to determine when and at what levels a relatively recent new product introduction would peak, assuming different price erosion rates. Normally the model chooses the price erosion rate based upon the assumptions input; however, the model also allows for a manual override of the price erosion rate. This feature is particularly useful when evaluating the impact of a price war upon the industry volume. In this case, the objective was to optimize the dollar return within a specific time span. The PLC model was used to make strategic decisions relative to price and production in order to accomplish this objective. The price was allowed to erode at various rates from slow to rapid. Changes in both the timing and level of industry activity were observed. Techniques unrelated to the PLC model were then used to estimate changes in market share and to accomplish the financial analysis. However, it was the timing and magnitude of the industry turning point that was critical to the analysis. After the fact tracking of actual results was consistent with the

FIGURE 2
Electric Housewares PLC's—Six Typical Examples



Source: Merchandising, January 1960 through March 1980, passim.

model predictions with respect to both timing and volumes.

Definition

The Product Life Cycle is a quantitative expression of unit sales volume of a specific product category (or class) from introduction to market demise. Product category (or class) refers to the total product line. For example, coffeemakers would be a product category, whereas perk or drip coffeemakers are substitutable forms of the product. As such, the new product form will take over a portion of the product category; later it also may become displaced by another form of the product (bonnet hairdryer replaced by salon, replaced by styling dryer, replaced by pistol dryer), while the original product category (hairdryers) continues to evolve on its own particular product life cycle. This product form substitution process is significantly different from PLC and should be viewed as such; otherwise some serious management misjudgments can be made by attempting to apply PLC theory to product form substitution situations. Likewise, it is equally fallacious to apply PLC theory to brand or market share situations that are dependent upon a completely different set of variables. Product form substitution and brand share situations will not be discussed in this paper since they involve separate and distinctly different concepts.

Product sales volume is composed of two elements: initial purchases, or saturation of the product's target universe, and replacements of units that have worn out, been broken, or become obsolete. In the early stages of the PLC, initial purchases constitute the majority of sales volume; however, as ultimate saturation is approached, the replacement component usually becomes dominant (Figure 3).

PLC Model

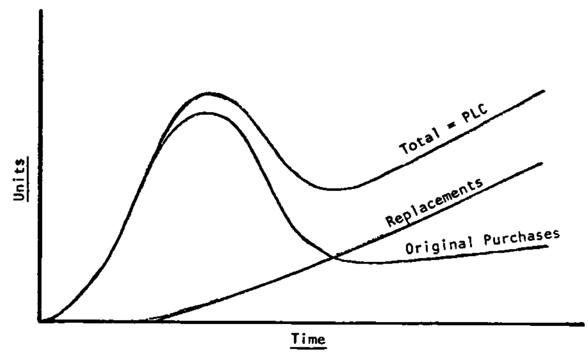
The PLC or industry volume is the sum of the original purchases and the replacement purchases as expressed below.

$$\text{PLC} = (\text{Original Purchases}) + (\text{Replacements})$$
$$I_{t_0} = [(U \times S)_{t_0} - (U \times S)_{t_{-1}}] + K(U_{t_0} \times S_{t_0})$$

Symbols used in the equation are defined below. Derivation and sources of data are discussed in the following paragraphs.

I—Total industry volume
U—Universe
K—Replacement constant [$K = 1/n(R)$]

FIGURE 3
Components of Product Life Cycle



S—Saturation
R—Percent of owners who will replace
n—Number of periods to replace
t_0—Current period
t_{-1}—First preceding period

Projections of target universe (e.g., households or demographic segments) are normally available from secondary sources. Adequate definition of target universe may be the more complex task, requiring a full understanding of actual product applications versus intended applications. Also, products with potential multiple uses within a given segment of the universe may require specific provision for multiple saturation of the total universe or some fraction thereof.

Original Purchases

Pertinent variables were first successfully identified by studying the saturation curves for existing products with the most diverse shaped life cycle patterns and noting the major differences that existed in the marketplace for these products. Not all of these major differences were readily obvious. For example, it was obvious that price level was a major constraint to the level of saturation that could ultimately be attained. However, it was not obvious that it was necessary to use the lowest price at which the product could normally be purchased in order to develop a relationship with a reasonable degree of consistency. Also, the need to define the target market adequately was not readily evident at the time, although now it seems that it should have been intuitively obvious. Other observations were more evident but were less easily quantified. For example, knowledge of the marketplace indicated that products in a highly aggressive market environment tended to saturate at a higher rate than those in a less aggressive market environment. But how does one quantify the relative aggressiveness for a single product in the marketplace? A combination of three variables provided such a measure. They are consumer need/want, the number of competitors, and the amount of advertising and promotional effort applied in the marketplace. Price erosion rates were also studied in the same manner. Products having the most diverse price erosion rates were studied. Price erosion rates were calculated in the traditional manner where the log of the price is expressed as a function of the log of the cumulative volume. It was noted that prices eroded more rapidly when competitors were very aggressive in the marketplace.

Equations expressing these individual relationships were then combined in the model in an iterative process that simulates the forces at work in the marketplace; i.e., when the price is relatively high, the model allows only a small percent of the target universe to participate in the market, but when the competitive aggressiveness becomes great, the price erodes rapidly, ultimate saturation is increased, and penetration of the ultimate saturation is enhanced. It is the interaction of these causal marketing factors that determines the shape of the saturation curve. Because individual man-made situations such as price wars have dramatic impact upon price erosion rates, a manual "over-ride" feature has been incorporated into the model in order to evaluate the impact of price erosion rates other than would be expected under the assumed conditions. This feature can also be used in conjunction with other assumptions to evaluate high side opportunities and low side risks.

The importance of advertising in creating awareness in the introductory phase of the PLC, and the consequent influence on saturation levels is intuitively obvious. However, limited study of products with significant fluctuations in industry advertising levels during relatively mature periods of the PLC indicated that the influence of advertising levels on saturation continues well past the introductory phase. Additional analysis would be required to evaluate the nature of advertising fluctuations and determine if advertising levels were solely responsible for increases in saturation or if product enhancements (potentially the basis for advertising increases) increased the inherent value of the product to the consumer.

Although a relationship exists between the degree of competitiveness in the marketplace and price erosion, the complete relationships with the number of competitors are not clearly understood. The authors assume that the causes include:

- Improved breadth of distribution as each additional competitor brings his specific distribution channel strength to the industry.
- Improved depth of distribution resulting from competitors' product niche selections.
- Increased product availability resulting from competitors' inventory building to support product launches.

Consumer relevance is incorporated in the model as an index that serves as a surrogate for the product's intrinsic value to the target universe. This value is acquired through consumer research techniques and also serves as the first screen for concept success or failure.

Replacements

Replacement volume is influenced by:

- Product's useful life (time from purchase to failure, breakage, or obsolescence)
- Percent of owners who will replace
- Practicality of repair versus replacement
- Level of initial purchases (saturation)

Development of the replacement constant requires knowledge of or assumptions regarding the useful life of the product and the owner's propensity to replace the product when its useful life is over. For early stage PLC projections, replacement characteristics for similar products have proven adequate; however, as a product progresses from introduction to maturity and the replacement constant becomes more significant to projection of total industry volume, refinement of replacement constant assumptions becomes necessary and the consideration of alternate replacement scenarios may become advisable. Particular attention to the owner's replacement propensity is mandated by introduction of competitive products that are functional substitutions for the current product being projected.

Validation

The methodology used to validate this model included the use of data for a number of products having the most diverse life cycle shapes to establish the necessary relationships to construct a composite model. Then, after developing the composite model from data related to these very diverse product life cycles shapes, two validity checks were executed. The first validity check was to test the capability of the model to predict the life cycles for the products used to develop the model, using actual data for these products and comparing the results

FIGURE 4
Validity Test 1

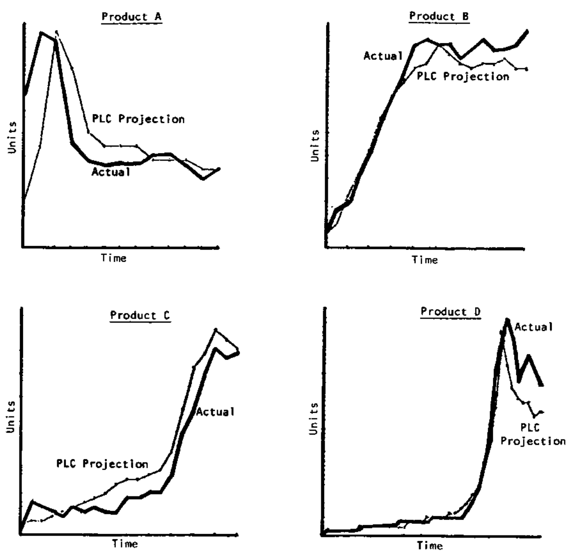
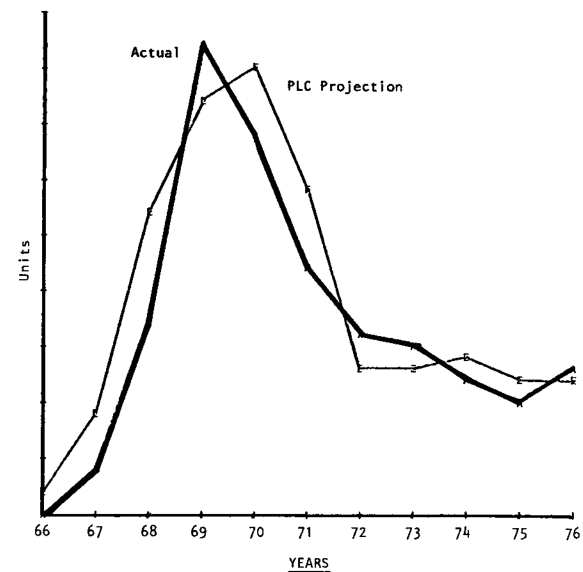


FIGURE 5
Validity Test 2—Product E



of the model forecast with the actual industry history. The results of this validity check are illustrated in Figure 4.

Although there are some significant percent differences in projections for specific periods, the PLC shapes predicted by the model were substantially accurate. The second and more significant validity check involved testing relatively new product introductions that were not used to develop the model. The results of one of these tests are illustrated in Figure 5. To date, validity checks have tended to validate the model to a substantial degree.

Other tests (where data was available) indicated that the component parts of the life cycle predictions (original purchases and replacements) were consistent with actual data, and predicted saturation and price erosion rates were essentially accurate. These additional checks were conducted to provide confidence that the individual equations in the model are accomplishing their intended purposes accurately, and to eliminate the concern that total industry predictions have been accurate because positive errors were balanced by corresponding negative errors within the individual routines of the model.

Exogenous Influences on the PLC

Other influences altering the PLC shape include economic cycles, supply constraints, labor disputes, material shortages, and software development lag. These influences are exogenous to the PLC model but their impact can be overlaid upon PLC through additional analysis. Two methods for accomplishing such modifications are suggested in the following examples.

Economic Cycle

In the early stages of the PLC development, the effects of the business cycle have been crudely approximated by applying zero-sum factors to the basic model predictions (Figure 6). Additional analysis will be required to refine the factor ranges

FIGURE 6
PLC Modified for Economic Cycles

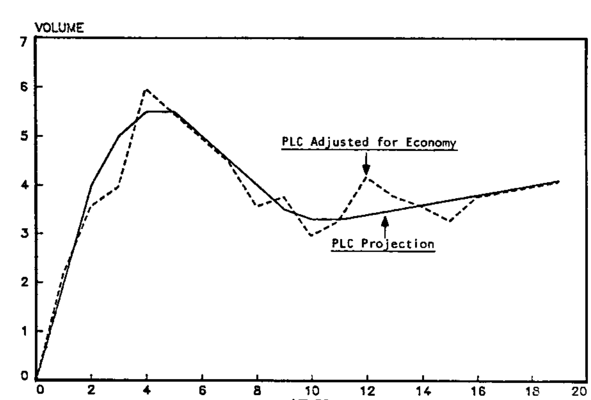


FIGURE 7
PLC Adjusted for Software/Programming Lags, Television/Electronics Industry

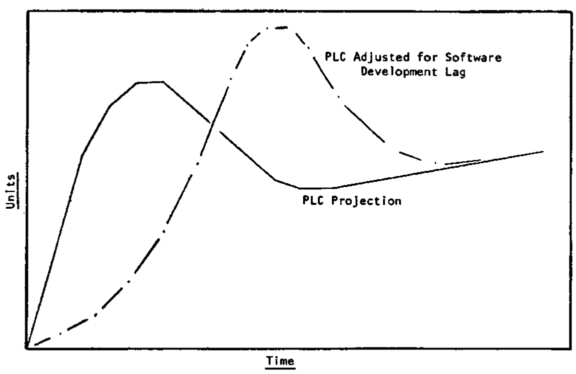
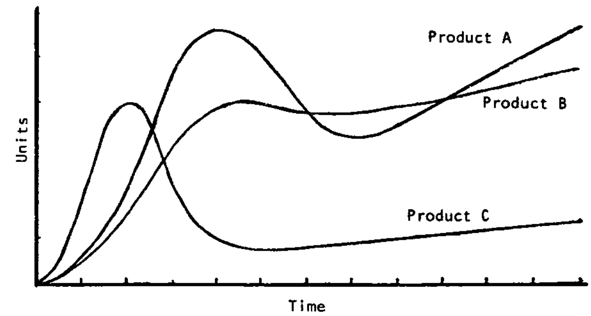


FIGURE 8
Evaluating Product Alternatives



and establish the basis for factor assignments consistent with economic cycle predictions.[3]

Software Evolution

Attempts to apply the model in industries other than that for which it was developed disclosed major variances that were determined to be related to the evolution of related software. To obtain accurate results, a routine was incorporated to apply quantitative indices of software development and availability. During the early days of television, the hardware preceded the programming or software. Indices ranging from zero to one were used to represent relative degree of national programming available. This tends to shift the PLC curve to the right and causes it to peak higher, as in Figure 7. Inasmuch as opportunities to apply the software evolution technique are limited, the success of the routine is currently undetermined.

Strategic Implications

The authors view strategic planning as a systematic process for allocation of resources to achieve an established set of corporate goals. In this regard, PLC projections provide guidance in answering critical questions such as which businesses should the company enter, and which products merit investments for feature and productivity enhancements. Other benefits of the PLC model include evaluations of opportunities and risks, direction of research, development of strategies, and determination of the product's compatibility with company structure and philosophy.

Opportunity Assessment

When presented with the three hypothetical opportunities represented by the most likely cases, the PLC projections depicted in Figure 8, management has the basis for informed evaluation of the proposals.[4] While a "bigger the better" mentality would favor Product A, a company with limited financial resources could, among other options, elect to forego the opportunity as a result of inability to participate adequately, seek additional resources independently or in a partnership arrangement, or attempt to participate through licensing. Product C, if it happened to be a low entry cost product, might represent a quick in/out opportunity for a company with some temporary excess capacity.

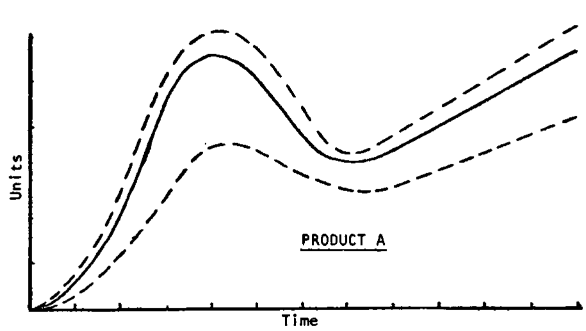
Risk Assessment

Because it is unlikely that either research or analysis will provide sufficient data to permit reliance on a single set of assumptions, the model facilitates evaluation of alternate scenarios. Figures 9 & 10 illustrate the ranges of expectation for Products A and B previously depicted in Figure 8. These ranges would have been defined as the result of the selection of assumptions input by the user(s). It is inherently easier to evaluate the reasonableness of each individual assumption than it is to evaluate the reasonableness of the PLC output that is the result of all the individual assumptions. In this example, Product B's most likely case projection

[3]In maturity, the effects of the evolution of the mix between original purchases and replacements and the availability of sufficient historical data will probably favor development of a causal econometric model for the product.

[4]It is assumed that management is concurrently knowledgeable regarding resource availability, technical capabilities, and other company strengths and weaknesses critical to success.

FIGURE 9
Assessing Risk—Product A



was constructed near the mean of the likely scenarios, while the most likely case for Product A was near the highest likely scenario. The authors favor a review of the underlying assumptions of both the best and worst case scenarios for any proposal to ensure that the nature of the risks and their impact is understood.

Research Direction

One result of the risk assessment may be the identification of variables requiring further research before commitment of resources. If the range of values for Product A in Figure 9 is the result of varying the consumer relevance assumption, decisions to proceed or expand the research into consumer relevance would depend upon the quality of the research supporting the project and the magnitude of the resources to be placed at risk.

Strategic Development

PLC-based strategy development has been the subject of numerous papers, and an exhaustive treatment is beyond the scope of this article; however, the following examples illustrate the impact of differing operational strategies as reflected by the model. Rink and Swan (1979) have provided an extensive literary review of papers related to the PLC.

FIGURE 10
Assessing Risk—Product B

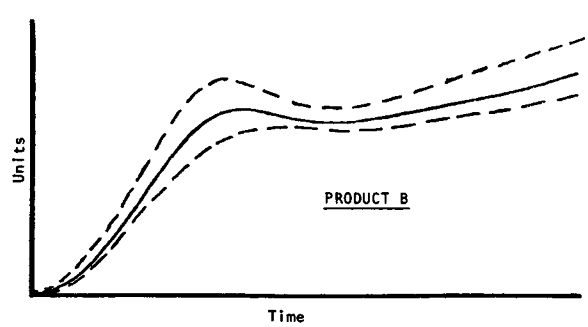
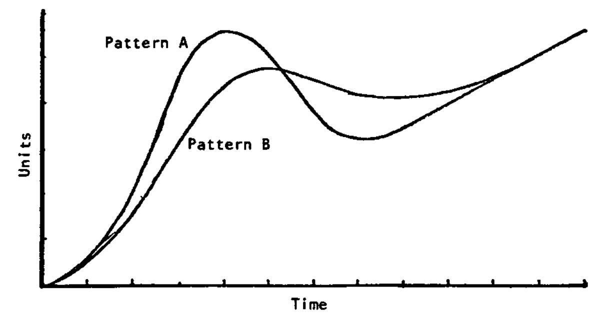


FIGURE 11
Pattern Management



Pattern Management. The PLC projections in Figure 11 represent alternate patterns for a hypothetical product based on varying assumptions regarding advertising, price, and competitive participation. While Pattern A represents the greater short-term unit volume, the capacity investment required for the industry to achieve the volume represented by the peak year is substantially greater than that required to support the volume sustainable during the product's mature years. In addition, the decline in volume following the peak typically results in an industry shake-out with resultant pressure on prices as departing participants liquidate inventories and the remaining competitors struggle to maintain volume and share positions.

If the company evaluating the product is the innovator, it has the maximum opportunity to control the PLC pattern. In the case of major barriers to competitive entry (e.g., unique technology, major capital investment requirements), the innovator has the option to hold pricing high and advertising levels relatively low until competitive threats become imminent. In the case of low entry barriers, the innovator may achieve superior results by driving for share through price reductions and high advertising expenditures.

An alternate to pattern management is available to latecomers in the industry: entry at the trough. Those products projected to experience extremely large variances between peak volume and trough volume present the opportunity for acquisition of the industry's casualties as the basis for a major participation in the product's mature phase. While this alternate involves the risk that suitable acquisition may not materialize, the option should not be ignored if the product's key cost elements are substantially consistent with the company's strengths.

Participation Method Selection. Each competitor makes two critical strategic decisions with respect to its participation in a product class or form.

- Whether to attempt to lead the industry's product development activities or to imitate the developments of other participants.
- Whether to manufacture the product or purchase it.

Although these decisions are neither irreversible nor absolute, it is significant that they be approached in an informed manner.

Leading industry product development implies a level of investment in technological and market expertise that is both high and sustained. A practical strategic approach involves segregation of the portfolio into leadership and imitation segments and allocation of resources accordingly. PLC projections represent one basis for this segregation; however, management must temper the attraction of high sales projections with a realistic evaluation of key success factors such as technology, underlying cost position, and market and distribution strength. Periodic review of the criteria for leadership designation is recommended.

The decision to manufacture rather than purchase is related to but not dependent upon the decision to adopt a leadership or imitation strategy. Cuisinarts, Inc. became the acknowledged leader in food processor industry product development while maintaining a purchasing strategy. Again, a practical strategic alternate would indicate a balance of purchasing and manufacturing, even within a product category. As an example, a company planning participation in a product with a projected PLC similar to the compressed Pattern A in Figure 11, could elect to invest in facilities adequate to support its projected share of the industry's sustainable volume in maturity and purchase additional requirements as necessary in the peak years.

Compatibility Assessment

Evaluation of the factors contributing to the development of the PLC provides the opportunity to determine the product's compatibility with the company's structure and philosophy. Structural compatibility includes the capability to participate at the pace indicated by PLC projections: a company with a highly structured product development and approval process (which implies a high degree of risk aversion) would better avoid participation in fast paced industries with PLC projections similar to those experienced in electronic calculators.

Philosophical compatibility includes the fit of the product to the company's internal and external image: A product which, because of technical considerations, is projected to exhibit a relatively short mean time to failure would typically be incompatible with a company that takes great internal pride and receives marketplace recognition for the durability of its products. Alternately, the company's image considerations could drive a technological solution to increase durability and create a preemptive product position.

Conclusion

The PLC model is a valid management tool for predicting the sales volume of a product class; however, its greater significance is related to developing the discipline of consciously addressing the factors that influence the shape and amplitude of the volume projections in order to access the opportunities and risks realistically. This discipline fosters the development of product and strategic alternates that can be evaluated using the model and become a logical basis for short- and long-range planning. The PLC model has been used within the housewares and electronics consumer goods businesses for these purposes. It has also been used in conjunction with other techniques to evaluate the impact of various price erosion rates upon the industry and the firm as discussed earlier in this paper. Because of the relative newness of the PLC model, the full potential of its possible uses has not yet been explored.

REFERENCES

Dhalla, N. K. and S. Yuspeh (1976), "Forget the Product Life Cycle Concept!," *Harvard Business Review,* 54 (January–February), 102–112.

Nielsen, Inc. (1967), "Identifying Phases in an Average Product 'Life Cycle'," *Nielsen Researcher,* 8, 3–7.

Rink, D. R. and J. E. Swan (1979), "Product Life Cycle Research: A Literature Review," *Journal of Business Research,* 78 (September), 239–242.

Weinhold-Stunzi, H. (1964), "Marktforschung und Unternehmevstrategie," *Die Unternehmung,* 18 (August), 11.