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**THE PRODUCT LIFE CYCLE CONCEPT:
BURIED OR RESURECTED BY THE DIFFUSION LITERATURE?**

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THE PRODUCT LIFE CYCLE CONCEPT:

BURIED OR RESURECTED BY THE DIFFUSION LITERATURE?

The Product Life Cycle (PLC) concept is a well-known marketing strategy and planning tool. The concept is based on a simple biological analogy of stages over a product's "life," which is intuitively appealing, but unfortunately has limited utility in practice. For such a prominent marketing tool, the lack of both a focus on consumers and a theoretical basis is surprising. Diffusion of innovation models and theory offer considerable promise to provide a theoretical basis for the PLC. To date, diffusion models have been limited to explaining and forecasting PLC sales patterns. This paper consolidates this literature to develop an over-arching conceptual PLC model and managerial tool for consumer durables. The approach defines the new PLC phases based on some key consumer trends during product-market evolution, resulting in a four-phased PLC model: Innovation → Imitation → Repeat → Substitute. New marketing strategy implications emerge for each phase due to this additional focus on consumers. The model is operationalized using diffusion models, thereby providing a basis for both identifying and predicting PLC transitions. The types of data that need to be collected to fully operationalize and test this PLC model are discussed. The new PLC model does not ignore variations in PLC sales patterns. Rather, it provides an opportunity to explain such sales pattern variations and determine the underlying conditions that lead to different PLC shapes. An empirical illustration of the new PLC model is presented.

Keywords: Product Life Cycle; Diffusion of Innovations; Consumer Durables

Submitted to Technology and Innovation Management Division

INTRODUCTION

Everyone knows the Product Life Cycle (PLC) concept doesn't really work – don't they? The academic literature seems to have all but buried the PLC concept. Indeed, the amount of attention bestowed upon the PLC in the academic literature over the years is probably due more to the inadequacies of the concept than to its utility. Despite this, most marketing textbooks still give it considerable attention. Though controversial, the PLC is undoubtedly still one of the better-known concepts in marketing.

To investigate this paradox, we present a selected history of the PLC concept. The origins of the PLC in marketing literature can, in fact, be traced back to a debate about the usefulness of the PLC concept. Representative of this debate are the pro-PLC article (Anderson & Zeithaml, 1984) and the widely cited *Forget the PLC Concept* article (Dhalla & Yuspeh, 1976).

In the fall of 1981, when the *Journal of Marketing* devoted a special issue to the topic, the need for further research into a revised PLC framework was identified. However, few have since taken up this challenge, with the last significant work extending the PLC concept appearing in 1989, by Lambkin and Day.

A key problem with the PLC concept is that it is based on an intuitively appealing and simple, but unfortunately inadequate, biological analogy of a product's "life." The four "stages" of the traditional PLC concept (introduction, growth, maturity, and decline) are defined by changes in the sales growth rate, which is assumed to adopt an "S" shape. Unfortunately, ample empirical evidence suggests that this "S" shape is often not an appropriate approximation of the PLC sales pattern, in which case the "stages" cannot be unambiguously defined. Further, even when the PLC sales pattern does usefully approximate an "S" shape, the PLC concept offers no guidance as to the timing of the transition between stages (Gardner, 1987; Rink & Swan, 1979). As such, the utility of the PLC concept as a planning tool for marketing managers is obviously questionable.

Another important deficiency of the PLC concept is the limited amount of information provided to guide marketing strategy (Wind & Claycamp, 1976, p.8). Essentially, strategy guidelines are based on the current and expected sales growth, together with the expected competitive intensity. However, apart from sales growth, consumers are ignored. While such a general strategic tool like a PLC concept can hardly be expected to include all elements relevant to marketing strategy formulation, such a disregard of consumers seems incredulous for such a prominent marketing tool.

A related stream of research, diffusion models,¹ has been proposed as a potential solution for many of these problems (Day, 1981; Gardner, 1987). In fact, this approach is specifically adopted in a few PLC studies (Easingwood, 1988; Midgley, 1981). More generally, a vast body of work has been concerned with modeling the diffusion of new products (Mahajan, Muller, & Bass, 1993). This research has made considerable advances in modeling and explaining PLC sales patterns. However, these models have not been integrated into a conceptual PLC model to provide a framework for guiding marketing strategy.

This paper draws on the diffusion literature to develop a conceptual PLC model that is useful as a managerial tool. The biological analogy is abandoned, as is the notion that stages can be defined based solely on the aggregate PLC sales pattern. Instead, diffusion theory is used to define stages over the PLC that can be used as a broad guide to marketing strategy formulation. This has numerous advantages. First, as it is based on diffusion theory, additional information on consumer trends is provided to guide marketing strategy. Second, since PLC stages are based on measurable consumer trends, they can be unambiguously identified via tracking studies. Further, the diffusion models provide a framework for predicting the transitions. Finally, the new PLC concept not only accommodates variations in PLC sales pattern shapes, but provides a basis for explaining them.

An outline of the paper is as follows. A new conceptual PLC model² is developed for consumer durables. This conceptual model is operationalized by drawing on existing work on diffusion models. The strategic and managerial implications of the new PLC model are discussed. An empirical illustration of the model is provided for several major household appliances. The paper concludes with a summary and discussion of future directions for this research.

A NEW PLC MODEL FOR CONSUMER DURABLES

A new PLC model for consumer durable products is developed below. First, we present the basis for the new conceptual model, and compare this with the traditional PLC

¹ A number of other terms such as new product growth models and aggregate sales models are also used in the literature to refer to this class of models. Strictly speaking, many models of this type, such as those which incorporate the replacement of durable products, encompass more than the diffusion phenomena. However, the term diffusion models is most commonly used in marketing.

² We use the term “new conceptual PLC model” to describe the contributions at the conceptual level and distinguish it from the traditional “PLC concept.” Later we will introduce the term “operational PLC model” to refer to the specific implementation developed in this paper of this conceptual model.

concept. Next, the new conceptual model of the PLC is presented. Finally, this conceptual PLC model is developed into an operational PLC model by using existing diffusion models.

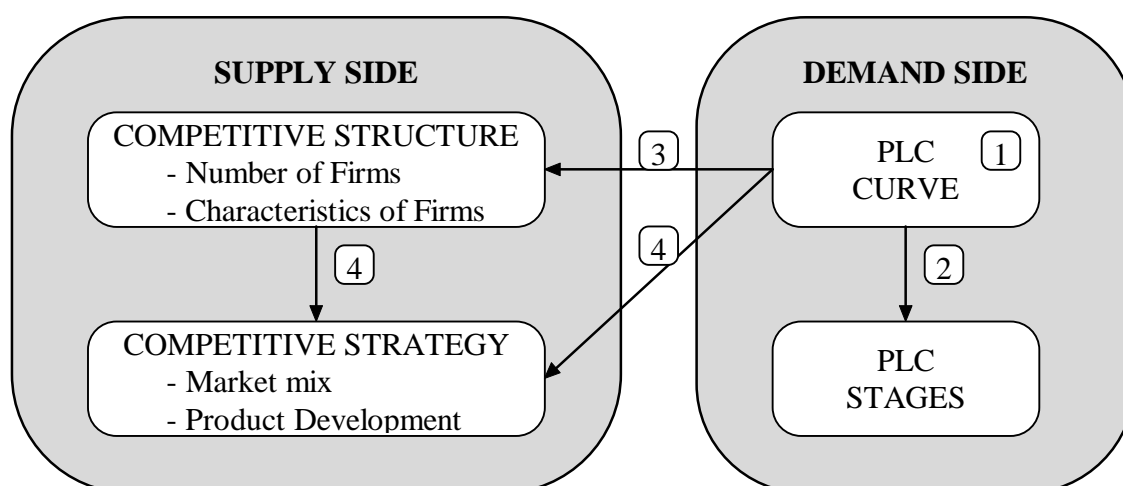
The PLC literature centers around what can be termed the “traditional PLC concept,” a version of which can be found in almost any general marketing text (e.g. Kotler, 2000). Though it is assumed that the reader is familiar with this concept, it is useful to re-examine its underlying assumptions. These are schematically depicted in Figure 1, and can be summarized as follows:

- (1) *Shape Assumption*: The PLC sales pattern can be approximated by an “S” shaped curve.
- (2) *Stages Assumption*: A number of distinct stages can be defined based on changes in the slope of this “S” shaped curve. Usually the following four stages are specified:
Introduction ↓ Growth ↓ Maturity ↓ Decline.
- (3) *Causality Assumption*: The supply side market structure and conditions, such as the number of competitors and intensity of competition, are driven by changes in demand,³ and are therefore different for each stage.
- (4) *Strategy Assumption*: Changes in sales growth and supply side conditions suggest different marketing strategies for each stage.

One issue that has received considerable attention is the level of analysis most appropriate for the PLC. Four levels have been suggested in the literature, namely brand, product form, product class, and industry. However, based on a review of the literature, Tellis and Crawford (1981, p.126) suggest “product forms bear the closest approximation to the PLC.” The rationale is that factors affecting brand sales are too unique to be captured by such a generalized concept. Similarly, industry and product class sales patterns are also diverse because each comprise such a unique mix of product classes and forms at various stages of the product life cycle. Hence, we adopt the product form as the level of analysis in this paper.

³ We use the terms demand side and supply side (of the market) throughout this paper in a classic economic sense. See Kotler, P. 1994. Marketing Management: Analysis, Planning and Control (8 ed.). Englewood Cliffs, NJ: Prentice Hall. for a more detailed description of those elements of the supply side which receive attention in the traditional PLC concept.

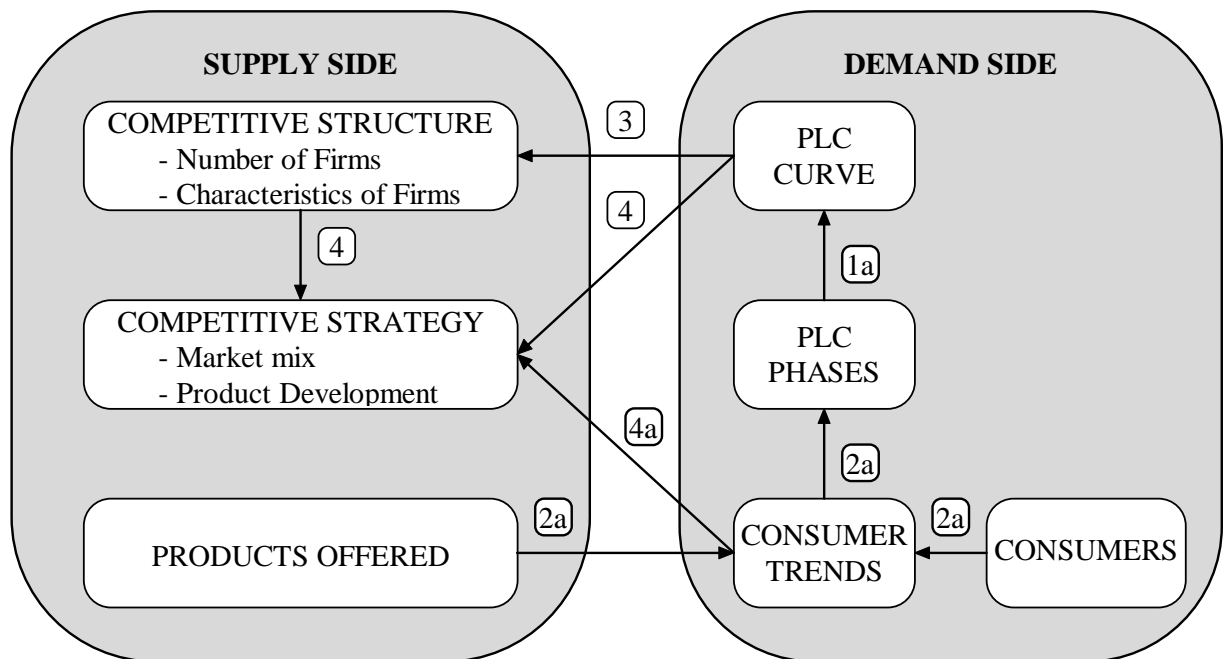
Figure 1: Four Assumptions of the Traditional PLC Concept



Schematically, the new approach is depicted in Figure 2. The altered assumptions are indicated by appending an “a.” Comparison with Figure 1 shows that while the basic structure of the traditional PLC concept is preserved, the details of the demand side description are altered. In particular, the starting point for analysis is now “consumer behavior,” rather than the “PLC sales pattern.” This is an important distinction from the previous diffusion literature investigating the PLC (Easingwood, 1988; Midgley, 1981), which focused on modifying the *Shape Assumption* (1a) by providing more accurate models of the PLC shape. The new model presented builds on this work in two important ways. First, the traditional *Stages Assumption* (2) of the PLC, which is based on changes in the PLC sales pattern, is abandoned. Rather, the traditional PLC stages are re-conceptualized as PLC phases based on underlying consumer behavior trends (2a). Second, diffusion models are used to provide a reasonably accurate but flexible description of the entire PLC sales pattern. This replaces the traditional PLC *Shape Assumption* (1a).

This important shift in emphasis has significant advantages for advancing the utility of the PLC concept. First, it provides a mechanism for explaining the various generic PLC sales pattern patterns, and thus ultimately enhances predictability. Second, it provides a theoretical basis for studying the dynamic nature of variations in product-market evolution. Finally, and perhaps most importantly, information on changes in consumer behavior is provided to guide marketing strategy (4a). Such information is surely essential for any prominent marketing tool.

Figure 2: New PLC Model



The Conceptual PLC Model

Traditionally, demand side PLC research has focused on the pattern of sales over time. Instead, the focus here is initially directed to changes in modes of buyer purchase decisions over the product's life. That is, several modes of consumer decision making are identified, which are dominant over some period(s) of the product-market evolution, but less prevalent during others. For consumer durable products, the following modes are appropriate:

- (i) first purchases versus repeat purchases;
- (ii) “innovative” first purchases versus “imitative” first purchases; and
- (iii) purchase decisions involving a choice between the incumbent product and a (new) substitute product versus purchase decisions without this choice.

We now define two features of the above conceptualization, namely the distinction between “innovative” first purchases and “imitative” first purchases, and a substitute product.

By definition, a new product form represents to the consumer an innovation. Diffusion theory (Rogers, 1983) provides the theoretical basis for the adoption of innovations. In his study of diffusion of innovations, Rogers contends that early adopters generally behave in a different manner to late adopters. He divides the population into five

categories according to their timing of adoption, then describes the underlying behavior of an average member of each group which leads to the timing of their adoption. Another categorization is introduced by Mahajan, Muller, and Bass (1993), which is again based on the time of adoption, though this categorization is grounded in diffusion modeling. However, it is more useful to divide the population according to an underlying individual characteristic such as innovativeness, rather than the individual's resultant timing of adoption. Such individual characteristics provide both a stronger theoretical foundation for modeling and a better basis for targeted marketing actions.

The behavioral trait which tends to vary most between early and late adopters is innovativeness. Midgley (1977, p. 49) defines innovativeness as being "the degree to which an individual makes innovation decisions independently of the communicated experience of others." Manning, Bearden, and Madden (1995) operationalize this construct and show that it is directly related to new product trial. Such a detailed measure is, however, too complex to provide a useful segmentation of adopters. This continuous measure of innovativeness can be usefully approximated for consumer durables by the following dichotomy of behavior:

- (i) purchases by consumers who buy the product before learning about its characteristics from earlier adopters (which we will term "innovative"), and
- (ii) purchases by consumers who refrain from purchase until being assured about the product from earlier adopters (which we will term "imitative").

Though this definition does not encompass the full complexities of innovativeness, it does provide a convenient, measurable way of distinguishing between two types of purchases, and reflects the notion of "innovativeness" for consumer durable products.

As previously discussed, we advocate the product form as the most appropriate level of analysis for the PLC concept. A substitute product, therefore, is another product form that performs the same core functional tasks as the incumbent product (though perhaps additional tasks as well). However, complete substitution is not an absolute requirement. That is, "partial substitution" is allowed for, as suggested by Day (1981, p. 64), so long as the substitute product is ultimately preferred to the incumbent product by a significant proportion of the incumbent's potential consumers. While in most cases it is expected that the market for the incumbent product will become non-viable, and that the product will be withdrawn, this is not a requirement. Thus, examples of product substitutions for consumer durables include various generations of IBM PCs, and compact discs players replacing record players.

A modified formulation of the PLC concept is now possible based on the above modes of consumer behavior. Three phases are defined, namely Innovation, Imitation, and Repeat, in which innovator first purchases, imitator first purchases, and repeat purchases, respectively, are the dominant form of current purchases. That is, the phase is defined according to the component of sales which is largest. Further, the time interval after which a substitute product form enters the market represents another phase we term the Substitute Phase. It is acknowledged that sales do not suddenly shift, for example, from imitative first purchases to repeat purchases; rather, a gradual transition occurs. However, it is useful from a PLC perspective to define distinct stages according to the dominant type of purchase occurring. Further, while there is no guarantee that a particular phase will exist for a specific product, in a typical case there will be: an interval in which innovator first purchases dominate; a later interval in which imitator first purchases dominate; and still later, an interval in which repeat purchases dominate; before finally, a substitute product is introduced. This results in an

Innovation ↓ Imitation ↓ Repeat ↓ Substitute

representation of the PLC as a modification to the traditional

Introduction ↓ Growth ↓ Maturity ↓ Decline.

Intuitively, the phases of this new PLC representation will often be related to the stages of the traditional PLC concept. Such an example is given in Figure 3, using the mathematical model developed in the next section. In this figure, the “total” PLC sales pattern is generated by adding the “first purchase” and “repeat” curves. In turn, the “first” purchase curve is generated by adding “innovative” first purchases and “imitative” first purchases. Also, all sales reflect the impact of a substitute product following its introduction. In this example, where the proportion of innovators in the adopting population is small, the Innovation Phase is characterized by a low level of sales, just as in the traditional Introduction Stage. Similarly, the Imitation Phase would often be a period of sales growth (similar to Growth Stage), while the interval dominated by repeat purchases is likely to have relatively constant sales, as in the Maturity Stage. Finally, like the Decline Stage, sales will probably be falling in the Substitute Phase.

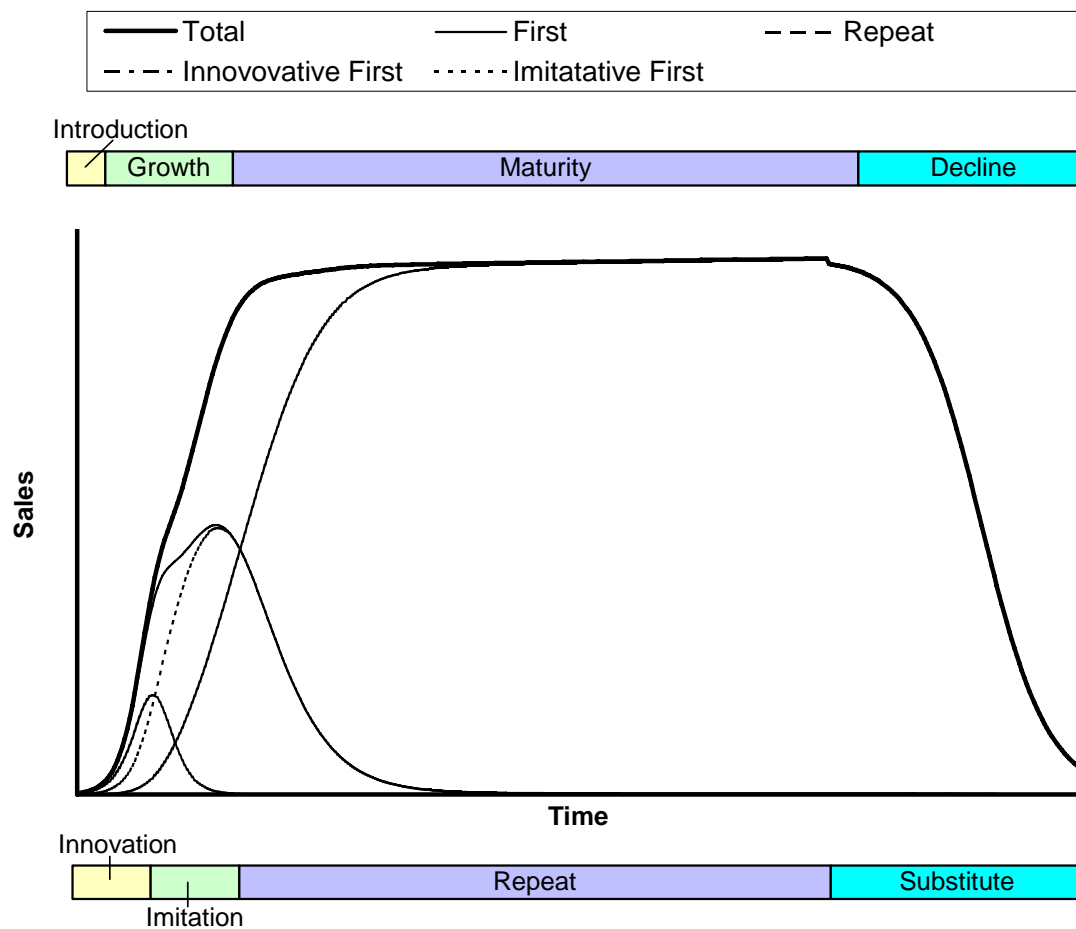


Figure 3: An example of the Traditional PLC Stages and New PLC Phases

However, the length of these phases may vary significantly between products, resulting in very different product-market evolution patterns. For example, for some high technology products, the introduction of substitute products may occur so quickly that a Repeat Phase of the PLC is never reached. This would result in a very different product-market evolution, with very different strategic implications. Also, since the substitute product does not necessarily erode all of the incumbent product's market, a PLC may have two or more Substitute Phases as successive competing products are introduced. An important contribution of this new conceptual PLC model is that such variations in product-market evolutionary patterns are both accommodated and explained.

Operationalizing the Conceptual PLC Model with Diffusion models.

We develop an operational model based on the new conceptual PLC model. This must encompass the consumer trends identified in the previous section. To achieve this, three existing models from the diffusion literature are combined. Specifically, these are a first purchase diffusion model, a durable product replacement model, and a product substitution model. While the selected combination of models is certainly not the only one possible, it does capture the dynamics of product-market evolution described in the previous section.

The mathematical details of the resulting models are contained in Appendix 1. Below, the selected models are outlined and their choice briefly justified.

The first purchase model is based on the Steffens and Murthy (1992) model. This model is an aggregate level diffusion model that characterizes both the “innovative” and “imitative” purchase decisions in a manner consistent with the definition above. Further, it is demonstrated to well fit first purchase data for consumer durables. Supply side impacts, such as price and advertising, have not been incorporated in this, or any of the PLC component models. This decision is made in the interests of parsimony, though such an extension could be readily included.

The above model was modified to include the effect of a changing population, since population increase is an influential factor on the PLC for most products. An exponential model of population growth was used. It is acknowledged that this model of population growth is only valid when the given population is small compared to an upper limit that is imposed by considerations such as available resources. As a population approaches its saturation limit, the growth rate will slow. The exponential model was chosen for its simplicity and based on its excellent fit to historical data of US electrified households. If, however, the population is approaching saturation, or is declining, a different population model should be used.

The repeat purchase model is based on an approach introduced by Olson and Choi (1985) to represent replacement purchases. They assume the life of each unit to be a stochastic variable with a probability distribution the same for all units. A deterministic analog of this model is used in a manner similar to Kamakura and Balasubramanian (1987). The Rayleigh distribution is chosen as the form of the replacement distribution. This choice is again made in the interests of parsimony, as the Rayleigh is the only single parameter distribution that has been demonstrated to reasonably fit empirical data (Bayus, 1988).

The substitution model is based on the Fisher and Pry (1971) model. This is probably the most widely used aggregate model of product substitution, and, again, is extremely parsimonious, with only one parameter. However, it must be slightly modified here to accommodate only “partial substitution,” consistent with the new PLC conceptualization. Though the substitute product will be subject to the same influences of “innovative” and “imitative” first purchases, it is not considered beneficial to include this added complexity in this model. This is because the focus is on the incumbent product, not the substitute product. Hence, the distinction between “innovative” and “imitative” first purchases of the substitute product is of incremental benefit for a substantial cost in complexity. Since the model contains a discontinuity at zero level of product substitution, the model is modified to begin product substitution at an arbitrary small level. The result is a minor discontinuity observed in the PLC sales patterns illustrated in Figure 3.

MANAGERIAL IMPLICATIONS

The ultimate purpose of the new PLC model⁴ is to act as a broad guide for marketing strategy and planning. Advances are offered by the new concept in two important areas. The first is an improved basis to both define the current PLC phase and forecast future transitions. The second is to provide enriched information on consumer trends upon which to base marketing strategy. We elaborate on each aspect below.

The new PLC phases are defined according to either underlying consumer trends, or the introduction of a substitute product. These consumer trends which define the first two phase transitions, innovative and imitative first purchases and repeat purchases, are measurable concepts. Hence, the transitions between these phases can be determined in real time through tracking studies. Consequently, an initial managerial implication of the new PLC concept is that benefits, in terms of improved guidance to marketing strategy and planning, can be gained by conducting such studies. The primary benefit is the ability to identify these transitions, which signify meaningful changes in underlying consumer trends. As such, improved guidance is offered for marketing strategy formulation, as elaborated below. The second major benefit is that this additional data, combined with the diffusion

⁴ Above we refer to the “new conceptual PLC model” and the “operational PLC model” for clarity in their development. Throughout the remainder of the document, for brevity, we refer simply to the “new PLC model,” which encompasses both aspects of the model.

models underlying the concept, provide a mechanism to predict these transitions. The issue of prediction will be discussed further in the following section.

The transition to the Substitute Phase is defined by the introduction of a competing product which ultimately erodes a significant part of the incumbent product's market. As noted above, it is not possible to definitively determine whether a new product introduced will achieve this. However, it is possible to assess the likelihood of the new product's success through either managerial judgement, market research (Roberts, Nelson, & Morrison, 1995), or experimental methods (Urban, Hulland, & Weinberg, 1993). Further, competitive intelligence and environmental scanning techniques may assist in forecasting this transition.

We now elaborate on the specific implications of the new PLC model for marketing strategy. We do this by comparing typical marketing strategy guidelines of the traditional PLC stages with those for the new PLC phases. Doing so, we recognize that the new PLC phases do not directly correspond with the traditional PLC stages. However, as demonstrated in Figure 3, a reasonable level of correspondence in the timing of stages and phases is not unlikely. Further, since the traditional PLC stages are somewhat hazily defined anyway, a lack of exact correspondence is not considered to significantly detract from the comparison of strategies below. However, that being said, the empirical analysis in the next section suggests that the most dramatic managerial implications of the new PLC model occur where little correspondence exists between the traditional PLC stages and the new PLC phases. Hence, where significant discrepancies exist in the timing of stages versus phases, a more complex interpretation of Table 1 is required.

Table 1 provides a comparison of the major alternative marketing strategies between the traditional PLC stages and their "corresponding" new PLC phases. The table for the traditional PLC is taken from Kotler (2000), which was chosen as representative of presentations of the traditional PLC concept. In Table 1, only points of departure from the traditional PLC are listed for the new concept (in italics). Of course, the usual caveat applies that these are general strategic directions suggested by the PLC model, not prescriptive strategies to be strictly adhered to.

The first thing to note in Table 1 is the number of characteristics and marketing strategy suggestions that are either different or modified (over 50 percent). These points of departure all stem from the new characterization of consumer trends over the PLC. This high level of impact on marketing strategy is not surprising, given the central role consumers play in marketing.

The customer characteristics for the first three phases of the new PLC, of course, flow directly from the definition of these phases. For the Substitute Phase, it should be recognized that, initially at least, innovative consumers will switch to the substitute product, leaving imitative consumers as the customer base for the incumbent product. Additionally, given we are dealing with durable products, imitative customers might defer replacements of their existing units. In contrast, the customer characteristics reported by Kotler are derived using diffusion theory as a basis for explaining the PLC sales pattern. However, in doing so, the common mistake is made of directly equating the PLC sales pattern and Rogers' (1983) adoption curve. Of course, these can only be directly compared in the rare instance that repeat purchases of any kind are nonexistent. In any event, the customer characteristics erroneously reported do not appear to be critical in determining the subsequent marketing strategy suggestions. Hence, the consumer information provided by the new PLC should be seen as additional, rather than conflicting, information.

This additional consumer information results in additional direction in terms of marketing objectives, product strategy, and advertising and sales promotion, as shown in Table 1. A few points of clarification and justification are warranted.

During the Innovation Phase, while the product strategy should indeed include only a limited number of offerings, these offerings should ideally be fairly full featured in nature to appeal to the more innovative customers. However, this decision must be made in the context of development cost and competitive launch time issues. Promotion should stress these features and the novelty of the product.

During the Imitation Phase, potential would normally exist to expand the number of product offerings to meet the needs of a wider cross section of the market. Since imitative customers are being targeted, advertising might be used to stimulate word of mouth or emphasize the product's acceptance. In this context, warranty is also likely to be an effective tool.

During the Repeat Phase, competitive strategy recommendations that relate to defending market share remain valid. In addition, strategies to induce "unforced" replacements (Bayus, 1988) are sensible. These earlier replacements grow the overall market and may be at the expense of competing brands in which case market share is also increased. Typical strategies of this kind include product modifications such as styling and feature enhancements. This effort might be further supported with advertising, to communicate modifications and sales promotions and to directly induce early replacements.

Table 1: Comparison of Traditional PLC Stages and New PLC Phases

Traditional PLC Stage	Introduction	Growth	Maturity	Decline
New PLC Phase	<i>Innovation</i>	<i>Imitation</i>	<i>Repeat</i>	<i>Substitute</i>

CHARACTERISTICS

Sales	Low	Rapidly Rising	Peak	Declining
Customers	Innovators	Early Adopters	Middle Majority	Laggards
	<i>Innovative dominant</i>	<i>Imitative dominant</i>	<i>Repeat dominant</i>	<i>Repeat / Imitative dominant</i>
Competitors	Few	Growing Number	Stable number / beginning to decline	Declining Number
				<i>As above plus substitute product</i>
Costs	High / customer	Average/customer	Low / customer	Low / customer
Profits	Negative	Rising	High	Declining

MARKETING OBJECTIVES	Create product awareness & trial	Maximize market share	Maximize profit while defending market share	Reduce expenditure and milk the brand
	<i>As above plus target innovators</i>	<i>As above plus target imitators</i>	<i>As above plus target and stimulate repeat sales</i>	<i>As above plus target imitators</i>

STRATEGIES

Product	Offer a basic product	Offer product extensions, service, warranty	Diversify brands and models	Phase out weak items
	<i>Offer a single, full feature product</i>	<i>Diversify product offerings, increase service & warranty</i>	<i>As above plus product modifications</i>	
Advertising	Build product awareness among early adopters and dealers	Build awareness and interest in the mass market	Stress brand differences and benefits	Reduce to level needed to retain hardcore loyals
	<i>As above plus stress benefits and novelty</i>	<i>As above plus stress acceptance and encourage word of mouth</i>	<i>As above plus stress modifications</i>	<i>Reduce levels, stress acceptance</i>
Sales Promotion	Use heavy sales promotion to entice trial	Reduce to take advantage of heavy demand	Increase to encourage brand switching	Reduce to minimum level
		<i>As above but take advantage of word of mouth</i>	<i>As above plus to encourage early replacement</i>	<i>Increase to induce early replacements</i>
Price	Use cost-plus	Price to penetrate market	Price to match or beat competitors	Cut price
				<i>Price competitively with substitute</i>
Distribution	Build selective distribution	Build intensive distribution	Build more intensive distribution	Go selective: phase out unprofitable outlets

Finally, after entering the Substitute Phase, the substitute product obviously becomes a major form of competition. Since the new product will initially attract innovators, the primary objective is to retain imitators as long as possible. Hence, communication strategy should stress the accepted nature of the incumbent product, but levels should be reduced to reflect a shorter time horizon for returns on advertising. Pricing obviously needs to be made

with reference to the substitute product, though the pricing objective is altered as well, to maximize returns over a shorter time horizon. Promotions, however, would probably increase to induce some early replacement before the widespread acceptance of the substitute product.

EMPIRICAL ILLUSTRATION

In this section we illustrate the application of the new PLC model for five consumer durable products. The purpose of this section is not to examine the validity of the individual components of the mathematical specification of the model (first, repeat, and substitution components), since this has been reported in the original publications of these models. In fact, the key results of the new conceptual PLC model are largely insensitive to the exact choice of models for these individual components. Rather, three specific aspects of the PLC model are investigated. First, the ability of the model to specify PLC stages that are useful for marketing strategy formulation is illustrated. Second, the way the interaction of the model components explains PLC shape variations is explored. Finally, the suggested approach for predicting the transition between stages is presented.

Model Fitting

To illustrate the application of the new PLC model, we used empirical data for five consumer durable products. Disaggregate level data for innovative and imitative first purchases are not available. However, adoption data and sales data are available, which can be approximately decomposed into first purchase and repeat purchase data. The substitute model component is used for only one product, black and white televisions (B&W TVs), as no substitute products have yet been launched for the other four products.

The data used for this empirical analysis comes from two sources. The data for color TVs comes from commercial surveys reported in Bayus, Hong, and Labe (1989). This data set disaggregated total sales of color TVs into first purchases, replacement purchases, multiple purchases, and institutional purchases. The first and replacement data series were used for this analysis. The data for the other four products, B&W TVs, dishwashers, room air conditioners, and clothes dryers, comes from various publications of *Merchandising Week*. The total PLC sales pattern is generated from reports of annual total shipments of these products for the domestic US market. To disaggregate this data into first and repeat purchases, data of annual penetration levels for these products is used. Cumulative first

purchases are approximated by multiplying this penetration by the number of electrified households in the US. This data is then differenced to give annual first purchase sales.

The PLC component models are then fitted to this data as follows. First, the population increase is modeled by fitting the exponential growth model to the electrified household data. Next, the Steffens and Murthy (1992) first purchase model is fitted to the first purchase data. The parameters are estimated by a nonlinear least squares method analogous to that proposed by Srinivasan and Mason (1986) for the Bass diffusion model. Finally, the repeat purchase model is fitted to the repeat purchase data, using the fitted first purchase curve as the driving function, $f(t)$. Nonlinear least squares is again used to estimate parameters. For B&W TVs, for which the substitute model is relevant after 1961, the parameters of this model are jointly estimated with the parameters of the other models.

The results of fitting this model to the data for the five products are shown in Figures 4-8. These figures show the total sales data, the estimated PLC model, and its two components, first purchases and repeat purchases. In addition, the two components of the first purchase model, innovative first purchases and imitative first purchases, are displayed. The parameter estimates and some statistics of the fits are displayed in Table 2. Note that the population model estimates are not displayed, as they are common for each case. The estimate of μ is 0.021.

Table 2: Results of Fitting

Product	Parameter Estimates						MSE	MSE	R ²	R ²
	K _{INNOV} (millions)	K _{IMITAT} (millions)	α	β (10 ⁻⁶)	γ (10 ⁻⁶)	δ	First (10 ¹¹)	Repeat (10 ¹¹)	First	Repeat
Air conditioners	1.78	31.5	.0217	.425	.00565	.00740	1.65	7.26	.76	.26
B&W TVs	7.9	32.1	.00652	.343	.0124	.0134	9.15	9.94	.73	.72
Color TVs	11.2	38.1	.00306	.0666	.00517	.00458	1.72	1.09	.93	.92
Dishwashers	0.24	24.7	.0156	6.96	.00771	.00548	0.0896	0.540	.98	.86
Clothes dryers	2.83	34.0	.00057	0.299	.00407	.00253	0.985	0.637	.85	.81
Parameter Estimates										
		v		p						
B&W TVs		1.308		0.51						

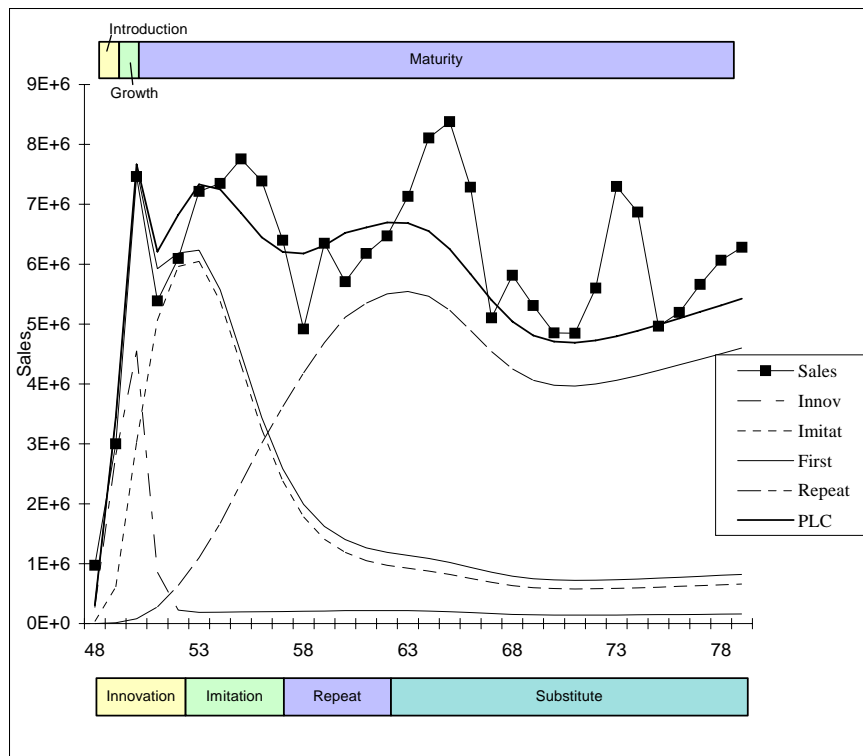


Figure 4: PLC Model Fitted to B&W Television

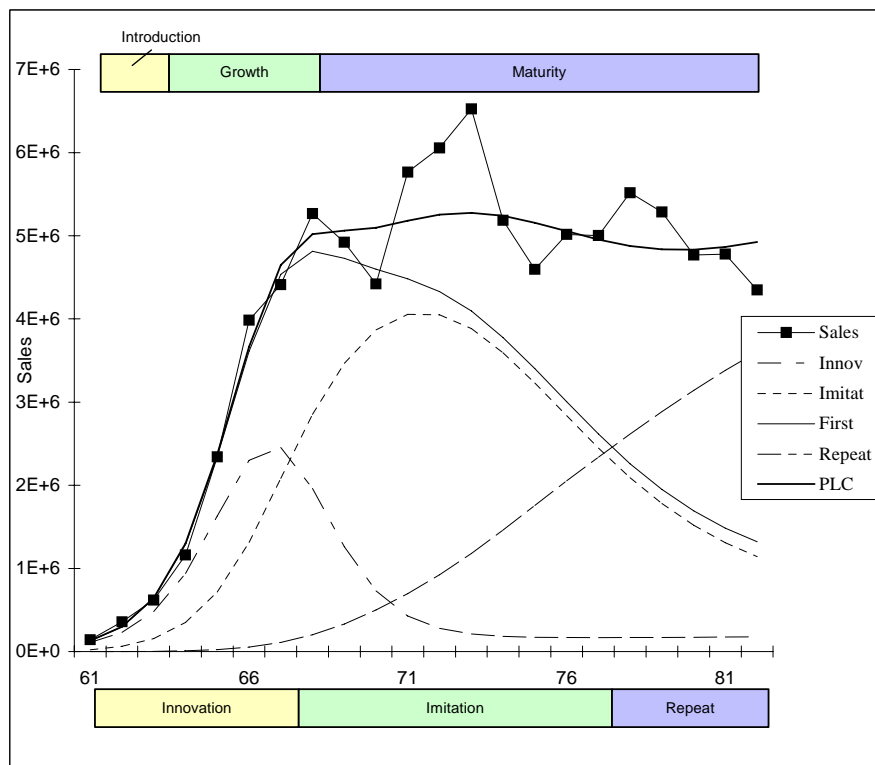


Figure 5: PLC Model Fitted to Color TV Data

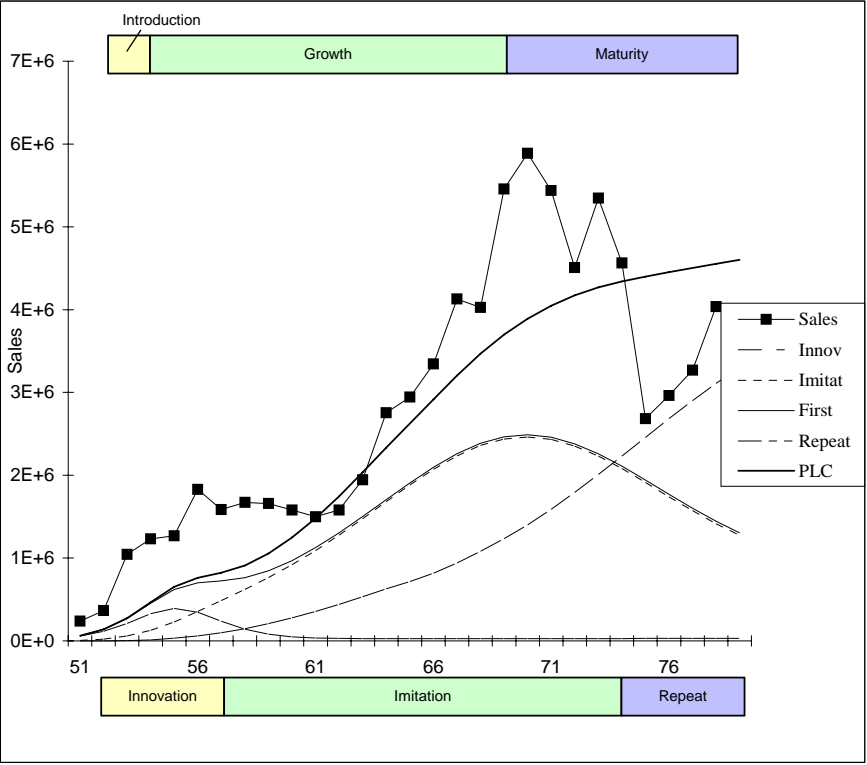


Figure 6: PLC Model Fitted to Air Conditioner Data

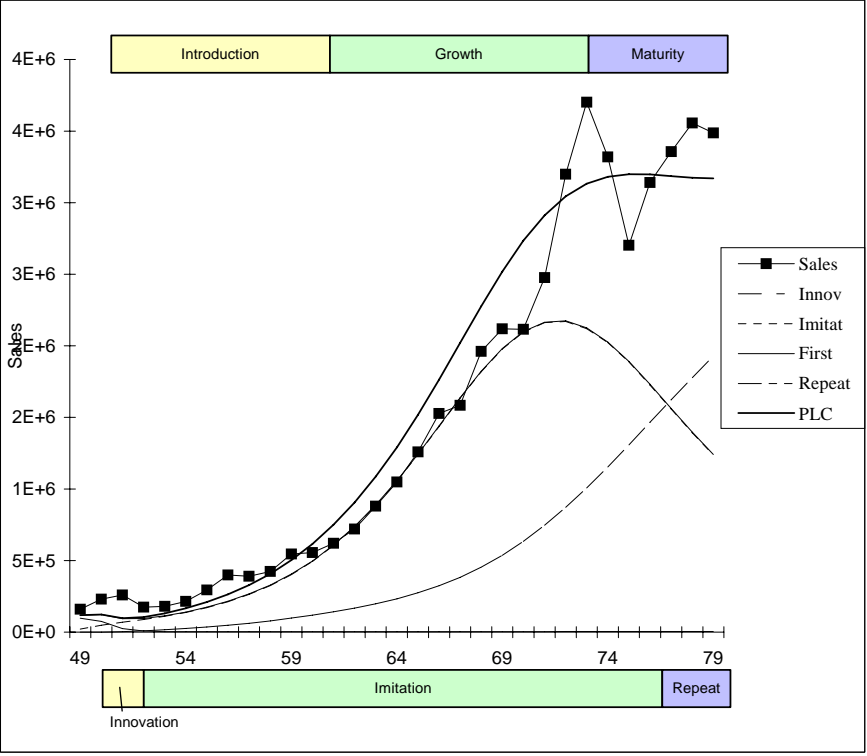


Figure 7: PLC Model Fitted to Dishwasher Data

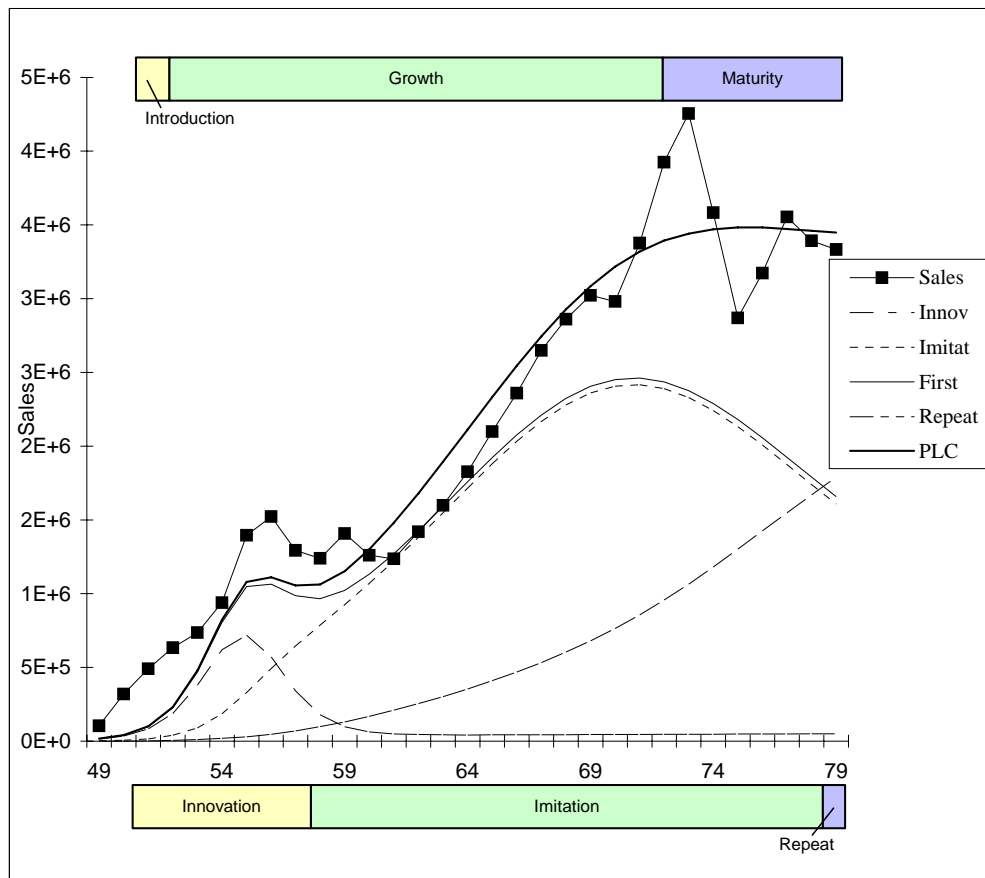


Figure 8: PLC Model Fitted to Clothes Dryer Data

It is noted that the fits for both the first and repeat purchase models are quite good in every case ($R^2 > 0.72$), except for the repeat purchases of room air conditioners. This poor fit is primarily due to a surge in repeat purchases from 1969 to 1973, and a lull in repeat purchases from 1976 to 1978. These fluctuations are not explainable by any data available to the author. However, while the model cannot account for these fluctuations, the estimation of the mean replacement age is nevertheless quite robust.

PLC Phases and Stages

To compare the new PLC model with the traditional PLC, the traditional PLC stages and the new PLC phases are both exhibited in Figures 4-8. An initial observation is that even defining the traditional PLC stages *ex post* is in itself problematic, particularly for room air conditioners, clothes dryers, and B&W TVs. For room air conditioners and clothes dryers, it

is evident that both the Introduction / Growth and Growth / Maturity transitions are difficult to identify. For B&W TVs, it is difficult to establish whether or not the downturn commencing about 1964 should be considered the onset of decline.

The new PLC phases offer many additional insights about the product-market evolution of these five products, not captured by the traditional PLC concept. Probably the most dramatic observation is the timing of the transition from Imitation to Repeat. For air conditioners, clothes dryers, and dishwashers the transition from Imitation to Repeat occurs about the same time as the end of the Growth Stage. However, for B&W TVs and color TVs the Growth Stage finishes before the Innovation Phase has even completed. This finding has significant managerial implications, because the shifting from targeting first purchase buyers to repeat purchase buyers is probably the most significant change in marketing strategy for consumer durables. This shift in strategy is not captured in any way by the traditional PLC concept.

Figures 4-8 also reveal that there are two distinct groupings of PLC sales patterns. For air conditioners, clothes dryers, and dishwashers, following the period of maximum growth rate, there is a gradual decline in the industry growth rate. This continues until the growth rate effectively reduces to near zero many years after the peak in first purchase sales. In contrast, for B&W TVs and color TVs, the period of maximum growth is immediately followed by a very rapid decline in its sales growth (to near zero), in only one or two years. This occurred because first purchases peaked around this time. In essence, color TVs and B&W TVs penetrated the market much faster than the growth of repeat sales. For B&W TVs this penetration was so rapid that the PLC declined for a number of years before repeat sales brought about an upturn.

This startling difference in PLC sales patterns is captured by the new PLC resulting in shorter Innovation and Imitation Phases before the start of the Repeat Phase. This phenomena is further explained by detailed examination and comparison of the underlying consumer trends in the figures. However, the traditional PLC does not account for such variations. These differences in the PLC sales patterns clearly have important managerial ramifications. In terms of production planning, the impact of such a rapid decline in growth rate is obvious. This finding also has an impact on competitive strategy formulation, which is known to be substantially influenced by industry growth rates (see Gardner, 1987).

Another substantial difference between the PLC patterns is the influence of innovative purchases. Clearly these are very significant for B&W TVs and color TVs,

moderately significant for room air conditioners and clothes dryers, and almost nonexistent for dishwashers. Again, this difference is not captured by the traditional PLC. This has significant managerial implications for promotional strategy during the early stages of the PLC, since innovators will adopt on the basis of external communications alone.

B&W TVs also exhibit a further significant difference between the traditional PLC stages and the new PLC phases. The onset of the Substitute Phase in 1961 is not captured by the traditional PLC concept. However, it had major ramifications for the marketing strategy for B&W TVs. Prices were drastically reduced, and product lines extended to include portable TV sets. These strategies are reasonably consistent with either the Decline Stage or Substitute Phase. However, for the traditional PLC concept, it is not clear where a Decline Stage should begin. Hence, the new PLC model captures this major shift in marketing strategy better.

The overall PLC sales pattern for B&W TVs displays an interesting tri-modal shape due to the combination of a variety of factors. First, there is a very early sales peak in 1951 due to rapid adoption by a relatively large number of innovators. Next, due to the fast diffusion of first purchases compared to typical replacement ages, there is a peak in sales around 1953 as discussed above. Then there is another peak around 1964, as repeat sales boost sales, but before the impact of color TVs depresses overall sales levels. Finally, sales start to rise again after 1970 due to the influence of continued repeat demand (B&W TV retains about half of its original market) and population increases. While the new PLC model both accommodates and explains this phenomena, the traditional PLC concept cannot.

A final difference occurs early in the PLCs, and is associated with the different shapes of the first purchase curves. In particular, clothes dryers and air conditioners have a bimodal first purchase pattern. This is due to an initial surge in innovative first purchases, followed by a lag before innovative first purchases accelerate. This flattening PLC sales pattern again has important implications in terms of production planning and forecasting not captured by the traditional PLC.

Prediction

The above empirical analysis demonstrates that the new PLC model does define some periods over a product's life, providing useful information for guiding marketing strategy. Further, the model captures some important variations in the PLC sales patterns for different products. However, the utility of the PLC concept is significantly enhanced if the PLC

transitions can be predicted. In this instance the concept may also be used as a planning tool to guide both product modifications and developments, and production planning.

An illustration of the approach to predicting the PLC Imitation / Repeat Phase transitions is presented. Unfortunately, data to thoroughly test the full capacity of the new PLC model to forecast transitions is not available. In particular, it is not possible to test the prediction of the Innovation / Imitation transitions since data for the individual components is unavailable. The aggregate first purchase data cannot be used since the transitions occur early in the PLC, and there is insufficient annual data available for parameter estimation.

The ability of the PLC model to predict the timing of transitions with the available data is examined. Forecasts were made 1, 2, 3, and 5 years ahead (of the actual transition year) by fitting the models to the early portion of the data series. The transition year is defined as the first year the repeat sales are larger than the first purchase sales. The results are displayed in Table 3. It was not possible to use the available data to predict this transition for B&W TVs. This is due to the very early occurrence of this transition. As a result, not enough annual data points are available to estimate the models. The average accuracy of the forecasts varied from 1.3 years for the 1 year ahead forecasts, to 3.5 years for the 5 year ahead forecasts. Note that the inaccuracy of the 1 and 2 year ahead forecasts is largely due to room air conditioners, where the predicted transition is actually less accurate for the shorter forecasts.

While the accuracy of the forecasts is not remarkable, it must be recognized that the transition forecasts are not required to be extremely accurate. The PLC phases are guides to slowly modifying marketing strategy over time, not distinct periods in which radically different strategies are employed. Using the example above, moving from the Imitation to Repeat Phase does not imply a rapid change of marketing strategy. Rather, a gradual shift in marketing emphasis towards repeat customers should occur.

Finally, it is not surprising that the transition forecasts are not highly accurate, given the quality of the available data and forecasting methodology. It is widely acknowledged that forecasting diffusion models based on early sales data is problematic. However, advances have been made using alternative methods such as analogy (Easingwood, 1988) and Bayesian updating of managerial estimates with sales data (Lilien, Rao, & Kalish, 1981); and recently, surveys have been found to greatly enhance early forecasting (Roberts et al., 1995). Unfortunately, appropriate data is not available to utilize these methods for the current application.

As discussed above, methods to predict the onset of the Substitute Phase include collecting competitive intelligence and environmental scanning. The empirical example involves the introduction of color TVs to substitute for B&W TVs in 1961. This example is complicated by the fact that color TVs were actually launched some years prior to 1961, but generated only insignificant sales prior to 1961, as there were no broadcast services offering regular color transmissions. Hence, the introduction of color TVs was not clouded in corporate secrecy and would not have been difficult to predict with some accuracy several years in advance.

Table 3: Predicting Imitation / Repeat Transition

Product	Actual Year	Predicted Year			
		1 Year Ahead	2 Years Ahead	3 Years Ahead	5 Years Ahead
Air conditioners	1974	1971	1971	1972	1972
Color TVs	1978	1977	1976	1976	1980
Dishwashers	1977	1978	1978	1978	1981
Clothes dryers	1979	1979	1979	1981	1985
Average Error (Years)		1.3	1.5	1.8	3.5

SUMMARY AND DISCUSSION

A fresh approach to PLC modeling is presented that abandons the traditional biological analogy and adopts a marketing theoretic foundation. Building on existing research in diffusion of innovations, an integrated conceptual PLC model is developed to guide marketing strategy. The four phases of the model for consumer durable products,

Innovation ↓ Imitation ↓ Repeat ↓ Substitute

are based on changes in the underlying buyer behavior trends. This conceptual PLC model is operationalized by utilizing a combination of existing diffusion models.

By incorporating consumer trends at the heart of the new concept, improved guidelines for marketing strategy emerge. Consumer behavior is notable in its absence from the traditional PLC concept, whereas the new PLC model is based on changing modes of consumer behavior over the PLC. As such, it provides invaluable additional information for

marketing strategy formation for each phase of the PLC. The value of the new PLC model to inform marketing strategy in this way was demonstrated empirically.

Whereas unambiguous identification of the traditional PLC stages is often problematic, the new PLC phases can be identified by tracking the underlying consumer trends upon which they are based. Further, the operationalization of the new PLC concept with diffusion models provides a mechanism to identify and predict phase transitions if appropriate data is collected. While suitable data was not available to adequately test the ability of the model to predict phase transitions, the approach was demonstrated with the data available. Data requirements and other approaches for improved prediction of phase transitions are discussed.

The operational PLC model also provides a basis for examining, explaining, and predicting variations in PLC patterns. This is true at both at the aggregate level of PLC shape, and also in terms of different patterns in the underlying consumer trends. The new PLC model embraces variations in PLC shapes rather than making restricting assumptions about the shape of the PLC sales pattern. The value of the new PLC model to inform marketing strategy in this way was demonstrated empirically.

The new PLC model, naturally, has many limitations. It is not as simple as the traditional PLC concept. No longer is a uniform four-stage life cycle description applicable to all products as a guide to product and marketing strategy. Instead, while the PLC is still described by a number of sequential phases, the duration and nature of these varies between products. Further increasing the complexity of the new concept are the diffusion models that underlie the description and prediction of these PLC variations. Essentially, realism has been increased at the expense of simplicity.

Only consumer durables are considered in this paper. Scope exists to extend both the conceptual and operational approach to other product types.

Finally, the supply side of product-market evolution has not been considered in this paper. In particular, supply side influences such as pricing, advertising, and product modifications are not included in the diffusion models. This exclusion is made in the interests of parsimony, and in an attempt to isolate the key points of commonality in PLC sales patterns. However, further empirical testing may reveal this to be an oversimplification. Further, more empirical work is certainly required to improve our knowledge of the coupled dynamics of supply side and demand side over the PLC. However, the PLC model presented here provides a platform for the demand side aspects of this research.

Appendix 1: Mathematical Specification of PLC Model

The first purchase model is based on the aggregate new product adoption (first purchase of durable product) model proposed by Steffens and Murthy (1992). This model differentiates between “innovators” and “imitators” in the adoption process. Innovators are defined as those willing to adopt the product without being informed of its characteristics from earlier adopters. Conversely, imitators delay adoption of the product until they are assured of the product’s characteristics by early adopters. The model is also modified to include an exponentially increasing population. The exact specification of the model is as follows:

$$\frac{dF_{\text{INNOV}}(t)}{dt} = (K_{\text{INNOV}} e^{\mu t} - F_{\text{INNOV}}(t)) (\alpha + \beta F_{\text{INNOV}}(t))$$

$$\frac{dF_{\text{IMITAT}}(t)}{dt} = (K_{\text{IMITAT}} e^{\mu t} - F_{\text{IMITAT}}(t)) \gamma F(t)$$

$$F(t) = F_{\text{INNOV}}(t) + F_{\text{IMITAT}}(t)$$

$$\alpha, \beta, \gamma, \mu > 0$$

where,

$F_{\text{INNOV}}(t)$ = cumulative number of “innovators” who have adopted at time t

$F_{\text{IMITAT}}(t)$ = cumulative number of “imitators” who have adopted at time t

$F(t)$ = total number of adoptions (first purchases) at time t

K_{INNOV} = initial total number of “innovators” in potential population

K_{IMITAT} = initial total number of “imitators” in potential population

The repeat purchase model is based on an approach proposed by Olson and Choi (1985) to represent replacement purchases. They assume the life of each unit to be a stochastic variable with a probability distribution the same for all units. We use a deterministic analog of this in a manner similar to Kamakura and Balasubramanian (1987). By assuming the number of sales is large, the proportion of products that fail can be equated to the probability of failure. It is also assumed that all consumers immediately replace a failed product. The resulting equation for repeat purchases is given by the following integral equation:

$$r(t) = \int_0^t [f(t-a) + r(t-a)] h(a) da$$

where

$r(t)$ = the sales rate for repeat purchases at time t ,

$f(t)$ = the sales rate for first purchases at time t ($dF(t)/dt$),

$h(a)$ = replacement age probability density function.

We choose the Rayleigh distribution as the form of the replacement distribution for this illustration. The density function of the Rayleigh distribution is given by

$$h(a) = 2 \delta a \exp(-\delta a)$$

$$\gamma > 0$$

The substitution model is based on the Fisher and Pry (1971) model. It is given by

$$\frac{dS(t)}{dt} = v S(t) [p - S(t)]$$

$$v > 0; t > t_0$$

where

$S(t)$ = the fractional market share of product 2 at time t ,

p = ultimate market share for product 2,

t_0 = the time of introduction of product 2.

Since the model form does not allow for $S(t_0) = 0$, we impose the approximation that $S(t_0) = \varepsilon$, a small positive quantity. For the simulated studies, we assume $\varepsilon = 0.01$. This results in a small discontinuity in the PLC of the original product as seen in the figures.

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