Chapter

Understanding the Stages of the Product Life Cycle

Chinonso Kenneth Udokporo

Abstract

Originally formulated in the context of biological studies, the Life cycle (LC) concept was and now has become widely adopted as a framework for the interpretation and evaluation of phenomena that are subject to, and bound by the inevitability of change. The application of the LC concept to the development of industrial products is an important element in the administration of technological innovation. On this basis, therefore, it is referred to as the product life cycle (PLC). The concept of the PLC is used to support decision making in the management of product development. It may also be used in corporate strategy development, as well as the planning of activities and can be adapted to focus on technology deployment.

Keywords: product life cycle stages, introduction, growth, maturity, decline, management

1. Introduction

The management of the product development process is supported with the adoption of the product life cycle (PLC) concept, which is used as a decision-making tool. The PLC is used to describe the performance of the product as it advances through its life phases, from initial development until it is retired in order to fully exploit the utility of and the possibilities for profit at each phase of the life cycle [1]. While the product is in the market, the PLC phases are: introduction, growth, maturity and decline. With this in mind, the PLC becomes a representation of the product's market history and each phase is characterised by the trend of sales volumes and profit performance [2]. This supports the managers' decision-making efforts regarding possible intervention strategies – marketing arrangements to be taken, pricing considerations, product replacement, etc.

Given that the environmental performance of a product throughout its life cycle is influenced by the interaction between all the actors involved, an effective solution to deal with the environmental concern has to be considered in the context of the whole community of participants [3].

Ref. [3] states that with the consideration of the principles of industrial ecology, the activities of the community of participants should as a matter of urgency be considered within the context of the global ecosystem which comprises all living things, all land and water resources. Therefore, environmental analysis pays rapt attention to the life cycle of a product linked with all of its physical reality until it is disposed of.

Therefore, for an in-depth analysis focused on evaluating and reducing the environmental impact of a product, it is important to consider the manufacturing phases as well as the phases of preproduction of materials, use, recovery and disposal [3].

Considering environmental analysis, the product-system according to [4] is characterised by flows of resources transformed through the various processes comprising the physical life cycle. The LC processes that exchange substances, materials and energy with the ecosphere are the inevitable outcomes of the environmental impact of this product-system. According to the author, the different effects produced are in 3 main typologies:

1. Depletion – The exhaustion of resources, imputable to all the resources taken from the ecosphere and used as an input in the product-system.

2. Pollution – The totality of the events of emission and waste, caused by the output of the product-system.

3. Disturbances - The totality of the events of variation in environmental structures due to the interaction of the product system with the ecosphere.

Ref. [5] explored the possibilities of using the PLC concept in the management of private labels. Considering that private labels belong to a particular product brand, it becomes imperative to modify some aspects of the PLC, as it was developed on the basis of producer brands. For example, during the growth phase of the PLC, retailers expand brands to various product categories and apply the push approach while producers have an inclination towards widening their delivery network in the growth of their product brands and largely use the pull approach to achieve this. Also, there is a slight swing in focus from low-price strategy, mostly used in the introduction phase, to improving the quality and value in the subsequent stages of the PLC [5].

Ref. [6] emphasised the significance of considering the application of the PLC concept by procurement managers as increasing demands on cost reduction, supply sustenance, materials quality and the incidence of quickly changing technology and harsh competition have considerably expanded the scope of procurement, and elevated its significance at the corporate level [7].

2. Product life cycle stages

The PLC considers the features of a product(s) in terms of its LC. The life cycle theory is accepted as a decision making tool in management (of organisational structures of manufacturing activities; market analysis and forecasting based on the advancement of technologies; and the development of novel products and their introduction to the market) [3]. In light of this acknowledgement of the PLC concept as an analytical framework, there is the appreciation that both manufacturing activities, technologies and products themselves, theoretically develop as a result of an evolutionary route passing through different phases [3].

In the context of product management, in relation to market dynamics, the life cycle according to [3] is understood as the period during which the product is in the market. Refs. [6] in [8] suggested that the PLC is the fundamental variable in determining a workable business strategy. The PLC identifies the following successive four stages through which products progress [8–11].

2.1 Introduction

This phase occurs once a new product is conceived, fabricated and made available in the market [12]. This stage requires substantial investment because the product has to be accorded the best opportunity to yield profit. The characteristics

of this phase are a small market; low sales (as could be observed by a gentle upward slope in the classical PLC curve), and high cost of research and development. The beginning of this phase is also characterised by losses made before substantial gains start to be actualized as the product sales increase. Depending on the product type/category, the introduction phase may also be characterised by very little competition and high prices. Ref. [13] states that the main order winner (OW) at the introduction stage is lead time (time from concept to availability of design) and capability of design.

2.2 Growth

As the product enters this phase, it experiences rapid gains, which is indicated by a sharp rise in the classical PLC [12]. The main characteristic of this stage according to [13] is increasing demand and that the main OW is service level (the ability of the product delivery system to respond to unpredictable demand). Marketing and promotional activities are effective ways to generate/enhance customer demand. Other obvious characteristics of this phase are an increase in competition, lower prices (as a result of competitors entering the market), reduced support costs (due to production increasing to meet demand) and increase in profits (as a result of reduced costs).

2.3 Maturity

At this phase, the PLC curve begins to flatten out, organisations are more concerned about maintaining their share of the market, and therefore the mere existence of the product is not given a second thought. The maturity stage is known to last longer than others [12] and is characterised by a drop in sales, more competition, a reduction in market share, a reduction in profits, further reduction in costs, innovation (aimed at improving market share). Ref. [13] indicates that the main OW is cost after the product at this stage has been pushed to a kanban supply chain.

2.4 Decline

The market becomes saturated at this phase, demand for the product and hence sales start to witness a reduction in demand and sales, however, the rate at which the declines occur can radically differ from one product to another. The decrease in sales for some products may tend towards zero, while others remain at a steady low level for longer periods [12]. These disparities show that the end of the PLC curve may take on a variety of forms. This could be seen as the beginning of the end of the product. At this phase, costs see a further reduction, demand reduces, the market starts to decline as competitors gradually withdraw, sales volumes drop, profits are seriously affected and the product is ultimately withdrawn from the market.

Several other PLC models other than the classical PLC curve are found throughout literature. For example, [14] identified three PLC stages and three levels, namely, pre-development, development and post-development. The three levels are business level, product level and component level. The pre-development stage is concerned with the conception and diagrammatic representation of the product. Development deals with the physical representation of the product through research and prototyping. The post-development stage is concerned with production, sale and use of the product.

Ref. [15] identified three stages of the PLC namely, pre-use, in-use and post-use. The pre-use stage covers the life of the product from conception to the delivery. The in-use stage concerns the period when the product is being used by the customer.

The post-use stage comprises the period when the product's functional life at the hands of the customer has ended.

Considering these phases, the objective of the PLC theory is to describe the behaviour of the product from the start of its life until it is retired, so as to improve the value of and the chances for revenue [1] and to appropriately allocate resources. Therefore, the LC is seen as a depiction of the product's market history and each phase is characterised by the trend of sales volumes, demand and profit performance [2]. This helps guide the managers' decisions regarding possible intervention strategies – marketing actions to be taken, pricing decisions, product substitution, etc. Again, considering the product as an item that comprises both the intangible dimension (need, concept and project) and a tangible dimension (complete product), its LC can be understood as a pre-established arrangement of evolutionary phases wherein each phase is necessary for the execution of subsequent phases.

PLC has been identified as the fundamental variable affecting business strategy [5] as it provides an important perspective for the formulation of strategies [8], because each phase has distinct characteristics that affect the operation of a business. What may be necessary in one phase may be unimportant in another [8, 16]. That is to say that each of the product life cycle stages brings different challenges, opportunities and problems; therefore, it is necessary to adjust marketing, financial, product, sales and human resources accordingly to make the product as successful as possible [11] in [5]. Again, the classical PLC curve is bell-shaped and represents sales in the course of time through the four stages described above. Such a shape of the product life cycle curve is an inevitable theoretical generalisation because, in practice, different products have different life cycle curves, depending on the length of individual phases and the very product type.

The significance of the PLC is reflected in the idea that it directs attention to the market opportunities and threats that may have strategic implications. The PLC is a resourceful framework for formulating contingent hypotheses about suitable alternative strategies [13] in [17] and directing the attention of senior management towards the anticipation of the possible consequences of the underlying dynamics of the market being served. Ref. [18] argued that the PLC concept does offer a beneficial and challenging framework for a meaningful evaluation of the growth and development of a new product, a business, or an entire industry. Ref. [19] believe that differentiated competitive advantages should be formulated, and are necessary at different stages in the PLC.

3. Detecting PLC stages

The PLC would be more useful in strategy planning, but only if the time when a product changed from one PLC stage to another can be more accurately and unambiguously predicted [20]. However, there is not yet a consensus on the methodologies for identifying each PLC stage [21]. According to [22], there are very few generic quantitative analyses on how to determine the bounds of each stage. The same authors stated that 'owing to a lack of established phase identification methods, a few authors concluded that the model is useful for monitoring sales but is limited to forecasting [22]. Ref. [23] states that proof of the PLC as a concept is difficult to find and that the PLC tends to be limited in its applicability. However, the same authors acknowledged that the qualitative descriptions of the stages can be more easily recognisable.

Despite the doubts and inconsistencies inherent in the PLC concept, [23] believes that it has become one of the building blocks of management theory in

general. Ref. [11] also believe that PLC is likely a fundamental variable affecting business strategy.

Ref. [20] was able to identify the take-off point in the sales of colour television sets, or the transition from the introduction stage to the growth stage by using semilog paper to plot annual sales of colour sets as well as number of homes equipped with colour television, a difference analysis relative to the saturation of colour televisions.

An examination of the percentage change in real sales of a product from year t to year t+1 was performed by [24]. The authors assuming that the distribution follows a normal function plotted the observed changes as a normal distribution with mean zero; they also determined that if a product had percentage change less than $-{}^{1}/_{2}\sigma$, it was observed to be in the decline stage. A product with the percentage change exceeding, ${}^{1}/_{2}\sigma$ was in the growth stage. And if the percentage change was in the region $\pm{}^{1}/_{2}\sigma$, the product was said to be stable corresponding to the maturity stage.

Ref. [24] believe that their work is a good model of sales behaviour in certain market situations. However, they advised that the results of the tests conducted in it be interpreted with caution as many of the product forms are not sufficiently detailed. The performance of the model leaves some questions regarding its general applicability. Ref. [24] also acknowledged that many complex interacting forces affect sales. Forces such as seasonal fluctuations are not relevant to the LC model while rapid declines in currency (example: the dollar) value through inflation may cause changes seem to reflect the LC patterns but are in fact independent of them. Hence [24] adjusted all sales data used for their work to make provisions for population growth, change in the level of personal consumption and price changes.

Ref. [23] argues that [24]'s work appeared mostly anecdotal, or focused on a very small cluster of examples. Though [23]'s work did not concentrate on detecting the stage of the PLC (is focused more on brand life cycle-stability and durability), it sought to solve the problem of limited number of examples by adopting a much larger sample size from data collected by the British Marketing Research Bureau (BMRB) as part of their Target Group Index (TGI) and monitored over a longer period of time. The size of the TGI covered 25,000 British adults and this allowed a large number of brands to be monitored with some degree of comparability and accuracy in terms of questions asked and sample selection over a much longer period of time-20 years. Ref. [23] believes that the lesson learned from the PLC concept and its accompanying body of research is that it is perilous to ignore change. By extension, change could be the differences in life cycle stages and or the change from one life cycle stage to another.

Ref. [25] in [22] introduced the two measures of product life – catalogue life and, and commercial life – to determine the traditional life cycle model (M-PLC) stages in an investigation of the ethical drug industry in the U.S.A. Below is a summary of both [25] 's and [24]'s stage identification criteria (**Table 1**).

A forecast methodology was proposed for predicting both product life time (PLT) and non-linear PLC by [26], based on a two-stage fuzzy, piecewise regression analysis model. The authors applied a generation-based approach, which predicts PLC by deriving the annual fuzzy regression lines, based on the yearly shipments of earlier generation of products. It is possible to apply the proposed methodology in forecasting other multiple generation products like personal computers and semiconductor processes. Furthermore, the outcomes of the authors' prediction methodology can be applied as a basis for policy foresight and strategic definitions for each stage of the PLC. The authors of this work used historical data from consumer electronic components makers to conduct its empirical study assert that their proposed method successfully predicted PLT and PLC based on the available data.

Phases	Ref. [24]	Ref. [25]
Introduction	S_i less than 5% of peak sales	Up to 5000 new prescriptions in a single month
Growth	S_i^* greater than +0.05	From 5000 new prescriptions in a single month
Maturity	S_i^* in the +0.05 to 0.05 range	From maximum monthly revenue
Decline	S_i^* greater than −0.05	Below 20% or 10% of maximum monthly revenue

Symbols: Si = yearly sales of nondurable i divided by sales of all nondurables; Si = yearly percentage change in Si.*

Table 1.
Adapted from [22].

They also acknowledged that uncertainties always exist in marketing information as a result of errors, biases, or intentionally designed fault data.

Ref. [27] acknowledging that econometric tests of all the hypotheses on the form of consumer good PLCs have not been carried out at the time adopted a more mathematical method, providing several methods of estimating PLCs. One of the methods provided by [27] is [28]'s generalised least squares method which is plagued with some disadvantages as there is no description of a method for the derivation of significance limits for the parameters. Another problem with Marquardt's method is the difficulty in implementation.

Another method developed by [27] Brockhoff, (1967) is the iterative method which according to the author, provides a good foundation for [28]'s generalised least squares method. This method provides a good starting point, in that it helps eliminate the problem of parameter limits encountered in Marquardt's method. However, it may still be riddled with the other limitations identified with Marquardt's method beyond the parameter limits problem.

Ref. [29] discussed the purpose and usage of the PLC regarding the consumer durable goods industries. The authors focused on a model that could forecast the industry volumes of a newly introduced product through each stage of its life cycle. The model or industry volume is the sum of the original purchases and replacement purchases as given by:

PLC = (Original Purchases) + (Replacements).

$I_{t0} = [(U \times S)_{t0} - (U \times S)_{t-1}] + K[(U_{t0} \times S_{t0})$.

I = Total industry volume.

U = Universe (Example: households or demographic segments).

K = Replacement constant [K = 1/n(R)].

S = Saturation.

R = Percentage of owners who will replace.

n = Number of periods to replace.

t_0 = Current period.

t_{-1} = First preceding period.

According to [29], product sales volume is composed of two elements: initial purchases or saturation of the product's target universe, and replacements of worn out units, been broken units or obsolete ones. In the early PLC stages, initial purchases constitute the majority of sales volume; however, as ultimate saturation is reached, the replacement component usually becomes dominant.

Ref. [20] reports that that some researchers due to the problem of management having to make different decisions at each LC stage, proposed a different set of forecasting procedures. The evidence used to support these as [20] identified are two products of Corning Glass Works – glass components for colour television tubes and cookware. The reviewing authors cautioned that the recommendations of such works are grounded on inadequate empirical evidence, noting also that the user has

to know the PLC stage the product is in before the corresponding set of forecasting procedures can be adopted.

Other researchers according to the same review by [20] developed new product models which forecast the growth and maturity stages of a new product based on either test market data or pre-test research. However, these models are limited in accurately forecasting the second half of the PLC curve [20].

Some other authors/researchers chose to ask the companies producing, managing and marketing the products which life cycle stage their product(s) was in after carefully describing the product life cycle stages and their corresponding characteristics to the respondents. Where the respondents are fully engaged with the product (production managers for example and more closely so in the case of this research); i.e. overseeing a production process, drawing up and implementing a production schedule, managing costs, supervision duties, team building/management and as discovered through this research, duties more closely integrated with functions such as marketing, sales as well as finance this method of LC stage detection could be dependable because the respondents have sufficient relevant knowledge. However, this method could be subjective especially when there's not ample knowledge on the part of the respondents for a number of reasons which may include time spent in a particular company and managing a particular product or group of products.

Author details

Chinonso Kenneth Udokporo
University of Derby, Derby, United Kingdom

*Address all correspondence to: c.udokporo@derby.ac.uk

References

[1] Ryan, C., Riggs, W.E., 1996. Redefining the product life cycle: The five-element product wave. Business Horizons 39, 33.

[2] Cunningham, M.T., 1969. The application of product life cycles to corporate strategy: Some research findings. British Journal of Marketing 3, 32-44.

[3] Giudice, F., La Rosa, G., Risitano, A., 2006. Product Design for the Environment [Electronic Resource] : A Life-Cycle Approach/Fabio Giudice, Guido La Rosa, Antonino Risitano. Hoboken: CRC Press.

[4] Guinée, J.B., Haes, H.A.U. de Huppes, G., 1993. Quantitative life cycle assessment of products: 1:Goal definition and inventory. Journal of Cleaner Production 1, 3-13. doi:10.1016/0959-6526(93)90027-9

[5] Horvat, S., 2013. Application of product life cycle concept to private label management. Trziste/Market 25, 63-75.

[6] Rink, D.R., 1976. The product life cycle in formulating purchasing strategy. Industrial Marketing Management 5, 231-242.

[7] Rink, D.R., Fox, H.W., 2003. Using the product life cycle concept to formulate actionable purchasing strategies. Singapore Management Review 25, 73.

[8] Fullerton, R.R., McWatters, C.S., Fawson, C., 2003. An examination of the relationships between JIT and financial performance. Journal of Operations Management 21, 383-404.

[9] Meenaghan, A., Turnbull, P.W., 1981. The application of product life cycle theory to popular record marketing. European Journal of Marketing 15, 1-50. doi:10.1108/EUM0000000004881

[10] Yoo, C.S., 2009. Product life cycle theory and the maturation of the Internet (SSRN Scholarly Paper No. ID 1511853). Social Science Research Network, Rochester, NY.

[11] Anderson, C.R., Zeithaml, C.P., 1984. Stage of the product life cycle, business strategy, and business performance. Academy of Management Journal 27, 5-24.

[12] Robinson Jr., R.B., Pearce II, J.A., 1986. Product life-cycle considerations and the nature of strategic activities in entrepreneurial firms. Journal of Business Venturing 1, 207-224. doi:10.1016/0883-9026(86)90015-7

[13] Aitken, J., Childerhouse, P., Towill, D., 2003. The impact of product life cycle on supply chain strategy. International Journal of Production Economics 85, 127-140.

[14] Rausand, M., Utne, I.B., 2009. Product safety – principles and practices in a life cycle perspective. Safety Science 47, 939-947. doi:10.1016/j.ssci.2008.10.004

[15] Zeiss, R., Ixmeier, A., Recker, J., Kranz, J., 2021. Mobilising information systems scholarship for a circular economy: Review, synthesis, and directions for future research. Information Systems Journal 31, 148-183. doi:10.1111/isj.12305

[16] Abell, D.F., Hammond, J.S., 1979. Strategic Market Planning : Problems and Analytical Approaches/Derek F. Abell, John S. Hammond. London : Prentice-Hall.

[17] Day, G.S., 1981. The product life cycle: Analysis and applications issues. Journal of Marketing 45, 60-67.

[18] Hayes, R.H., Wheelwright, S.C., 1979. Link manufacturing process and

product life cycles. Harvard Business Review 57, 133-140.

[19] Nadeau, J., Casselman, R.M., 2008. Competitive advantage with new product development: Implications for life cycle theory. Journal of Strategic Marketing 16, 401-411.

[20] Rink, D.R., Swan, J.E., 1979. Product life cycle research: A literature review. Journal of Business Research 7, 219-242.

[21] Yan, Z., Zhao, Y., 2009. A new methodology of measuring corporate life-cycle stages. International Journal of Economic Perspectives.

[22] Cao, H., Folan, P., 2012. Product life cycle: The evolution of a paradigm and literature review from 1950-2009. Production Planning & Control 23, 641-662.

[23] Mercer, D., 1993. A two-decade test of product life cycle theory. British Journal of Management 4, 269.

[24] Polli, R., Cook, V., 1969. Validity of the product life cycle. Journal of Business 42, 385-400.

[25] Cox, W.E., 1967. Product life cycles as marketing models. The journal of business 40, 375-384.

[26] Chi-Yo, H., Gwo-Hshiung, T., 2008. Multiple generation product life cycle predictions using a novel two-stage fuzzy piecewise regression analysis method. Technological Forecasting & Social Change 75, 12-31.

[27] Brockhoff, K., 1967. A test for the product life cycle. Econometrica 35.

[28] Marquardt, D.W., 1963. An algorithm for least-squares estimation of nonlinear parameters. Journal of the society for Industrial and Applied Mathematics 11, 431-441.

[29] Harrell, S.C., Taylor, E.D., 1981. Modeling the product life cycle for consumer durables. Journal of Marketing 45, 68-75.