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ANALYSES OF PRODUCT LIFE CYCLE AND ITS PHASES VERSUS SME

Intense global competition, increased market uncertainty, rapidly evolving technology, rising cost and changeable customer preferences has big influence on modern companies. The global market requires quicker and more concrete responses. To stay on top of these complex dynamic processes a new kind of management is needed - that is product cycle management. Technology is moving at such a rapid pace that product life cycles (PLCs) are becoming shorter. Customers demand higher quality products, more quickly. The firsts life cycle phases are usually the most changeable period in terms of revisions on initial guesses about the total life cycle sales and peak sales timing. Identification of them is crucial because the information from the initial success or failure of the product is vital in determining the total life cycle sales and enable taking proper decisions. However, in the literature the turning points between stages are not clearly identifiable and there is always an amount of ambiguity in the transition between one stage and another. Identification of the phases is critical because if PLCs is appropriately supported, it can be indefinitely extended. This article by the use of Butler's model and mathematics allot points where the stages begin and end.

1. INTRODUCTION

Government-imposed barriers, which protect domestic markets, are falling rapidly. However, technological advances in production and transportation allow even the smallest firms access to customers, suppliers, and collaborators. Economic growth and innovation are fuelled increasingly by small companies.

Despite the acknowledged importance of small and medium-sized enterprises (SMEs) to the economy, there is too little statistical data on them [5]. Many of the observations describes what we already know of SMEs, for example the lack of time and resources to tackle issues. SMEs often complaint that they can't find clear, simple explanations of regulation that applies to their business. Many SMEs are unaware of the benefits and fear the costs and time needed to complete the process.

In the last few years a lot of attention has been attached to the analyses related to the management of companies, also to management by application of the product life cycle concept. However, studies of this sort, specifically in relation to SMEs, are very scarce and practically non-existent. On the other hand, with respect to the demands made by their environment, it seems as if these types of companies enjoyed a privilege. SMEs are an important driving force for economic growth and employment throughout the European Union.

2. PROBLEM FORMULATION

Today's industry is facing severe business condition, such as competition and increased market uncertainty. In these circumstances, a life cycle oriented approach, which evaluates and makes decisions based on expected profit through life cycle, is critical as a new management principle in the such industry. The planning and designing phases are the most important because about 85% of the life cycle cost is determined by the decision made in these phases [1]. For this reason profitable process planning based on decisions considering life cycle is essential to manage profitability.

Intensifying global competition, rapidly evolving technology, rising cost and changeable customer preferences has big influence on modern companies. Products are more complex. Customers demand higher quality products, more efficiently. Intense competition from the global market requires quicker and more concrete responses.

A successful product is often a unique one. If products were expected to behave as described in PLC, all of them would have been expected to go in the same direction, probably at the same pace, within the same period of time. Some products will fail during the development or test marketing stage. Even if brought to market, a product may perform below expectations. In short, the life cycle of any one product is uncertain, because technologies and market responses are uncertain.

The need for fast new product introduction has led to shortened life cycles for products in many industries. Products with life cycles of a few months to few years are very common in high technology industries e.g. computers and consumer electronics. A typical demand curve consists of rapid growth, maturity, and decline phases coupled with seasonal variation, caused by external market factors and sometimes factors internal to a company.

The scarcity of data on any given product in many short life cycle environments is offset by the availability of data of prior similar products. This data may give valuable information which can be used to examine the life cycle phases and futher to forecast PLCs of similar products, because complete life cycle demand history on a large number of preceding short-lived products is usually available.

To stay on top of these complex dynamic processes a new kind of management is needed which is called: product cycle management. The scheduling problem consists of determining when each vintage should hit the market.

The first life cycle phases are usually the most changeable period in terms of revisions on initial guesses about the total life cycle sales and peak sales timing. The information from the initial success or failure of the product is vital in determining the total life cycle sales. Replacing the corresponding values in the start-up forecast with the actual data and then running a least-squares procedure on the resulting data series may be one way to detect significant deviations from the initial guesses.

3. SURVEY THROUGH CYCLES OF PRODUCT'S LIFE

Product life cycle (PLC) is a popular concept in marketing and identifies four discrete stages of product: introduction, growth, maturation, and decline [3]. According to this concept a product usually advances through these stages. The PLC is a generalized model depicting the unit sales trend of some defined product from the time of its first placement on the market until the company removes it.

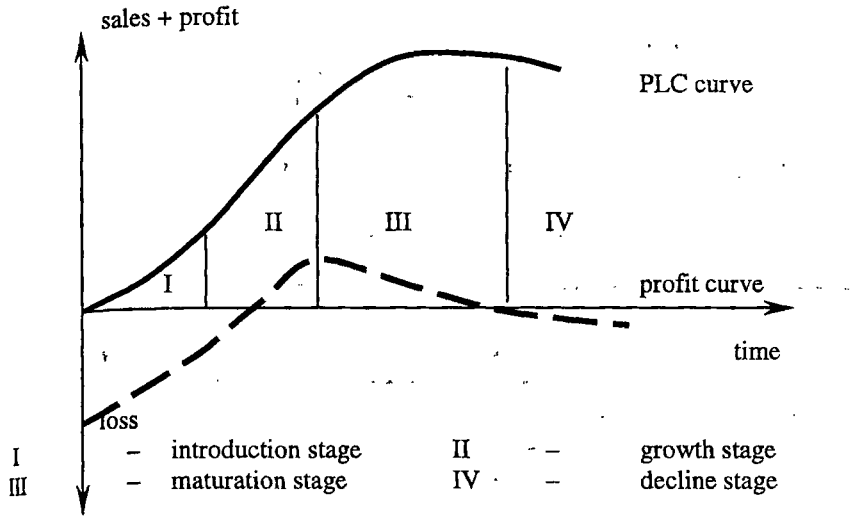


Fig.1. PLC and profit curve

PLC curve can be approximated by a bell or S-shape curve, which is divided into stages. Time length and the shape of such curve may vary for different products and industries. Un like a classical PLC curve, there are sharp changes from stage to stage, and the turning points are not clearly identifiable. Many products do not behave as suggested. A product may start out so strongly that it does not even go through a period of slow growth, whilst other my go directly into the decline stage without going through the maturity stage. In contrast, some products may never past the introduction stage. However, most products follow some type of PLC curve.

It is impractical to believe that a universal solution can be offered for all types of products, but it is still useful to provide framework consisting of general strategies concerning the four stages of marketing.

In a pioneering stage a high degree of uncertainty and risk is characteristic. The major challenge is to judge an uncertain environment and to cooperate with full-scale marketing to develop a sales forecast for the new product. New product will always involve a degree of uncertainty. Usually there is the limited number of competing firms, profitability is low, and prices are high.

The reasons for the changes of a product through its life cycle are due to [3]:

(*) instability of demand,

(**) instability of supply (competitive position).

(*) The first kind of instability seeks to explain the adoption of new products and services over time by consumers (the diffusion process theory). In introduction stage, a few persons are purchasing the product. If a product is successful, more buyers (early adopters) will come into the market, causing rapid growth in sales in the first phase of growth stage, whilst in the second phase a large number of buyers will follow. The sales in the maturation stage became relatively stable with the support of so-calles late majority group, and decline in the last group of laggard buyers.

(**) The second theory explains the behaviour of product life cycle in the market in which there are many companies, which are close substitutes for each other. To compete product differentiation is necessary to gain strategic advantage. The products psychological function is as important as its engineering aspect.

All products go through stages or cycles. The life of a product can almost be indefinitely extended, if appropriately supported. That is why it is **critical to identify and understand the stages that a product passes through**. The competitive characteristic will vary from stage to stage – some for the better, other for worse – requiring some timely adjustments in the market strategies.

Characteristics	Introduction (Pioneering)	Growth (Acceptance)	Maturation (Saturation)
Sales	Increasing slowly	Increasing rapidly	Stable
Target market	High income	Middle income	Mass market
Competitors	Very few	Highest	Stable number
Product modification	Frequent	Major	Annual
Production + market costs	High	Decreasing	Stable
Resistance to unfavourable conditions	Very poor	Pure	Good, depending on economic conditions
Parts + services required	Few parts, but frequent services	Large inventory	Complex + costly
Profit	Loss	Good	Stable

Tab.1. Characteristics of 3 first of PLC stages

4. DEMAND MODEL OF THE RESORT CYCLE [2]

4.1. Butler's life cycle model

In paper [2] the tourist growth patterns that could rise to a life cycle model has been examined. Different decisions among public and private organization are important for the speed and shape of the life cycle process. Changes to the theoretical structure (Fig.2.) are due to both the demand and supply side of resort expansion. The number of clients rise as new markets are penetrated. From the supply side, a number of activities (political and commercial decisions) interrupting the growth of life cycle path. Political decisions, like planning regulations, public investment (e.g. in infrastructure), partnership development, and financial incentives, which has great influence on life cycle curve are identified in [6].

This model correspond to classical PLC curve shown in Fig. 1., where Exploration and Involvement correspond with the early and late Introduction stage, Development and Consolidation correspond with the Growth stage and Stagnation represents the

Maturation stage. That is why the turning points between the stages in the Butler's life cycle model may represent the turning points between the classical PLC stages.

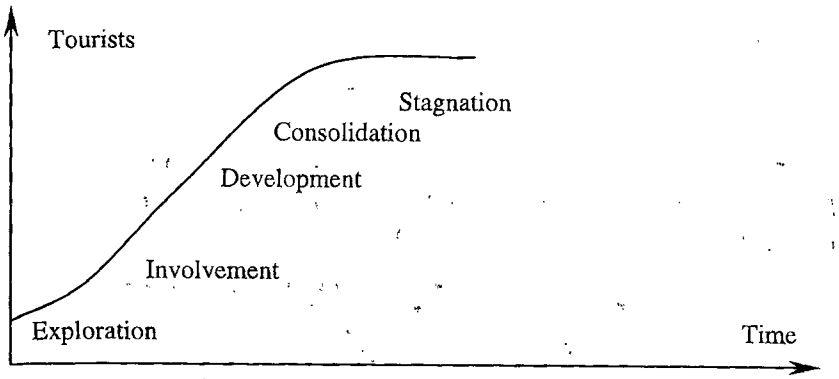


Fig.2. Butler's life cycle model

	Exploration	Involvement	Development	Consolidation	Stagnation
Characteristics:	▪ A few tourists; ▪ Unspoiled nature; ▪ Undisturbed local communities;	▪ Infrastructure is built; ▪ Tourism associations are created; ▪ Market is being defined;	▪ Attraction have been developed; ▪ Promotional campaigns raise; ▪ The novelty of the location is falling with the steady increase in tourists numbers;	▪ The volume of tourist is still growing , but at a decline rate; ▪ The destination is heavily marketed, ▪ Tourism is very essential for the local economy;	▪ The highest number of tourists is achieved; ▪ The resort is no longer fashionable ▪ There are problems with environment, culture, and changes in the local structure of industry;

Tab. 2. Characteristic of phases of Butler's life cycle model

4.2. Demand model [2]

The development begins when the first explorer starts to appreciate the qualities of D which is the number of consumers. While knowledge of D is growing, the market or segment is getting wider. This defines M, where M represents the potential market. At time t, M_t persons within M will have knowledge about D. M_t equals the actual market at time t, that is the number of people that have information on D at time t. When this situation is reached market penetration of D is complete.

$$M_t \rightarrow M \text{ for } t \rightarrow \infty$$

The information will spread to $M_t \times h \times dt$ persons in the period dt, where h express the velocity of awareness as D expands. There still are some $(M - M_t)$ persons yet to hear about D. The share of people who have not heard about D will be $(M - M_t)/ M$.
The total increase among the people knowing D during the time dt due to [2] is:

$$dM_t = M_t h \frac{M - M_t}{M} dt \qquad M_t < M \tag{1}$$

The time path (trend) of the actual market (for c=*const.*) is then:

$$M_t = \frac{M}{1+e^{-ht+c}}$$

for $c=h_{t0}$:

$$M_t = \frac{M}{1+e^{-h(t-t_0)}} \tag{2}$$

and because for t = t_0, $e^{-h(t-t_0)}$ =1, then t_0 is defined as the time where $M_t = M/2$. Equation 2 follows the pattern of a logistic curve and that is replicating Butler's life cycle path.

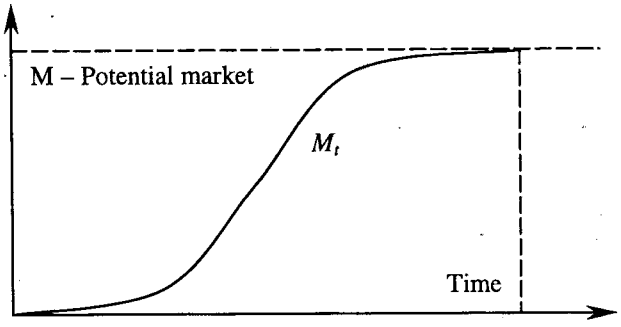


Fig. 3. Logistic Market Growth

M_t rises slowly at the beginning, because only few consumers have knowledge about *D*. As M_t increases, knowledge will rise also more rapidly. By the time knowledge of *D* is wide-spread, the increase slows down because there will be only a few people receiving the information about *D* for the first time, and when M_t approaches *M* asymptotically knowledge will finally stop.

There is an assumption made that each individual in the actual market has a probability *p* for visiting *D* at time *t*. The probability *p* is the average visit probability in the potential market. Thus, the number of consumers (v_t) at time *t* will be:

$$v_t = pM_t = \frac{pM}{1+e^{-h(t-t_0)}} = \frac{m}{1+e^{-h(t-t_0)}} \tag{3}$$

where:

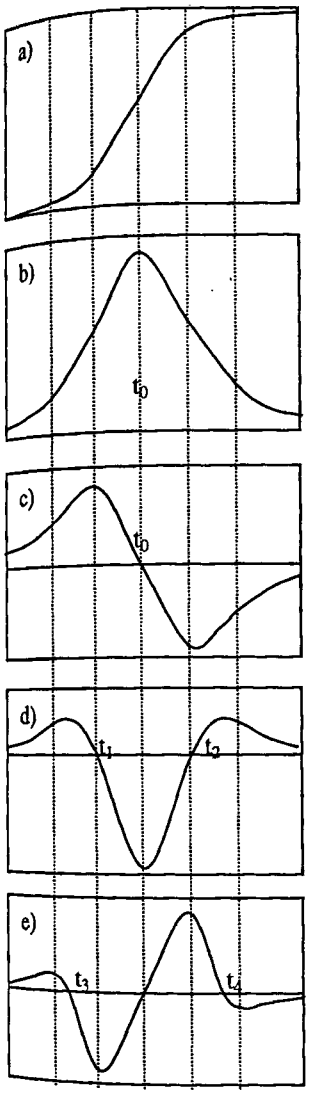
m – the number of consumers at the Stagnation stage.

The life cycle model is expressed in the form of a logistic function that may be manipulated to explain Butler's five stages in the development process.

In practice there is always an amount of ambiguity in the transition between one stage and another. Butler's stages are linked to changes in the behavior of the curve, which by the use of the mathematics can show as operational points where the stages begin and end. Formula (3) can be simplified by working with the relative number of consumers (the actual number divided by the maximum number *m*):

$$\omega_t = \frac{v_t}{m} = \frac{1}{1+e^{-h(t-t_0)}} \qquad 0 < \omega_t < 1 \tag{4}$$

(ω_t) – the relative number of consumers



$$\omega_t = \frac{1}{1+e^{-h(t-t_0)}} \qquad \omega_t \to 1 \quad t \to \infty$$

$$\omega_t^{\cdot} = \frac{d\omega_t}{dt} = \frac{he^{-h(t-t_0)}}{\left(1+e^{-h(t-t_0)}\right)^2} = h\omega_t(1-\omega_t)$$

$$\max \textit{ for } \quad \omega_t = \frac{1}{2} \quad t = t_0$$

$$\omega_t^{\cdot\cdot} = \frac{d^2\omega_t}{dt^2} = h^2\omega_t(1-\omega_t)(1-2\omega_t)$$

$$\max \textit{ for } \quad t = t_1$$

$$\min \textit{ for } \quad t = t_2 \qquad \omega_t^{\cdot\cdot} = 0 \textit{ for } \quad t = t_0$$

$$\omega_t^{\cdot\cdot\cdot} = h^3\omega_t(1-\omega_t)\left(1+6\omega_t^{\,2}-6\omega_t\right)$$

$$\max \textit{ for } \quad t = t_3 \quad \textit{and} \quad t = t_4$$

$$\min \textit{ for } \quad t = t_0 \qquad \omega_t^{\cdot\cdot\cdot} = 0 \textit{ for } \quad t = t_1 \quad \textit{and} \quad t = t_2$$

$$\omega_t^{\cdot\cdot\cdot\cdot} = h^4\omega_t(1-\omega_t)(2-\omega_t)\times\left(-12\omega_t^{\,2}+12\omega_t-1\right)$$

$$\omega_t^{\cdot\cdot\cdot\cdot} = 0 \textit{ for } \quad t = t_3, t = t_0 \quad \textit{and} \quad t = t_4$$

Fig. 4. The logistic curve and derivatives: a) the relative number of clients; b) increase in the number of clients; c) acceleration; d) change in acceleration; e) the invisible move [2]

a) **The rate of growth in demand** is measured by the first derivative of ω_t. The curve is increasing to a specific point, from where it falls, before finally approaching zero.

b) **The maximum value of the increase** is measured by the second derivative. The growth rate in the number of consumers has a maximum when their volume is exactly half of the long run maximum and t is equal to the defined t_0. The logistic curve is symmetric at this point. The point (t_0, $1/2$) is a turning point in the evolution of the destination. The second derivative measures acceleration and is positive for values $t<t_0$, zero for $t=t_0$ and negative for $t>t_0$. It increases to a point where the value of t is, which

depends on the velocity h. At this maximum, ω_t has the value 0.21 meaning that acceleration has a maximum when the number of consumers is 21% of the expected value. After t_0 has a minimum at $t=t_2$ (when the number of consumers reaches 79% of the value).

c) Changes in the rate of acceleration are described by the third derivative, which has its first maximum for t_3. The number of tourists is only 9% of expected maximum. The second maximum occur when $t=t_2$, corresponding to 91% of maximum volume. Beyond this point, the growth rate in the number of tourists is almost invisible.

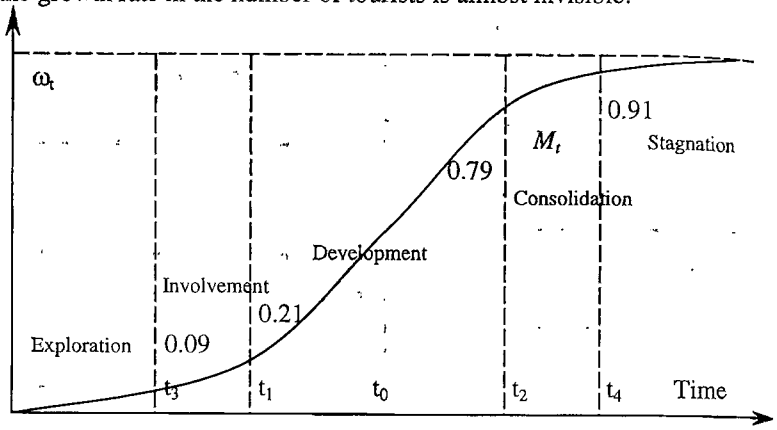


Fig. 5. Operational points where the stages begins and end [2]

Using the identified values of t it is possible to give relative values to the five stages in the life cycle.

- During the Exploration stage the number of consumers is below 9% of the maximum and rising moderately. The velocity at time t_3 is 1/3 of the maximum reached at t_0.
- The Involvement stage is characterized by a rapid acceleration in the velocity movement. The level of consumers reaches 21% of the expected future maximum.
- At the Development stage the growth of consumers increases to a maximum, and then the location establishes itself to the point where the volume of consumers exceeds 50% of the potential market. Acceleration has its minimum as time approaches time t_2. The reduced growth rate becomes apparent, although the velocity of increase is still two-thirds of the level at time t_0.
- At the Consolidation stage, growth significantly weakens. The destination is now well known in the market and consumers have risen from around 80% of the future maximum to about 90%.
- At the Stagnation stage there are two options for the future, Decline or Rejuvenation.

In this model the life cycle curve can only be a truly representative aggregation if all consumers are repeaters. Once non-repeaters are included in the market, the life cycle model becomes only a statistical approximation or caricature of reality and the "ideal" model and differs from the "ideal" time path with the rise of non-repeat consumers.

4.3. Clients' multiple and single visit to the market [2]

Probability p of visiting the D by each person in the actual market implies that there could be multiple visits by the same individual. However, there is often a segment of the market (attractions and events) that is visited only once. In such segment it is assumed that a consumer will only once visit D when knowledge of the resort is first obtained. In these circumstances, the velocity h is a measure of both the spread of awareness about D and an indicator of the strength of the consummation offer in determining the decision to visit. The number of consumers in this group (u_t) is equal to the increase in the market dM_t. Thus from (2) the first derivative of the logistic curve, has form:

$$u_t = \frac{dM_t}{dt} = \frac{hMe^{-(t-t_0)}}{(1+e^{-h(t-t_0)})^2} \tag{5}$$

That curve is very similar to the logistic curve until a maximum is reached, after that the number of consumers declines rapidly. If the entire market consists only of non-repeat clients, it is not possible to settle the market, when the peak has passed,

In a combined market where there are two segments: one for repeat consumers M_1 and one for non-repeat M_2 , the repeat segment, from (3) will be:

$$v_t = \frac{pM_1}{1+e^{-h(t-t_0)}} = mL_t$$

where:

m – is redefined for the repeat segment only; and L_t – is the logistic function,

$$L_t = \frac{1}{1+e^{-h(t-t_0)}}$$

From (5) the number of non-repeat consumers is:

$$u_t = \frac{hM_2e^{-h(t-t_0)}}{1+e^{-h(t-t_0)^2}} = hM_2(1-L_t)$$

The time path of consumer numbers (y_t) is:

$$y_t = v_t + u_t = mL_t + hM_2L_t(1-L_t) = mL_t(1+rh(1-L_t)) \tag{6}$$

where:

r – is the relation between the two segments and is defined as $r = M_2/m$

As $u_t \to 0$ as $t \to \infty$ repeat consumers will dominate the market at this stage, which implies, mathematically, that $y_t \to v_t \to m$ for $t \to \infty$. Further, the non-repeat consumers' share of the market is dependent on a high value of r. The condition for more non-repeat than repeat consumers is:

$$u_t > v_t \quad \text{if} \quad rh(1-L_t) > 1 \quad \Rightarrow r > 1/h(1-L_t)$$

5. CONCLUSIONS

The model presented in the paper and derived form tourist life cycle theory [2] serves for identification of the product life cycle phases, where the product is or will be. This could help to identify life cycle phase in which product occurs and also forecast future product life cycle phases.

To achieve this function, the model requires inputs, that are basically data (from the company history) which will be adopted to forecast the product demand function. Some mathematical models will be used to examine the history to build the curve of the life

cycle of products. Correspondingly the model will identify the operational points where the stages will begin and end (for each similar product).

Data required for the model are: the number of adopters (consumers) over a given time period (depends on the time granularity, e.g. over a month, or over a semester etc.); the sales levels over the same time period; the peak sales timing; the volatility in product prices (how the product prices changes); the potential market (the estimated overall market demand of the product).

Other descriptive data to fit the model to the product market features are: the type of the products produced (general description of the product, such as the branch); the distribution structure (how the market channel is structured, examples: mail-order distribution channel, or a channel for direct sales to commercial customers, or the discount-retailing channel, etc.)

The next step will be examination of proposed model on the basis of data from SME and on the basis of achieved solutions forecasting future stages of similar products from the same branch.

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