LIFE CYCLE OF A TECHNOLOGY AND IDEALITY

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ABSTRACT This paper presents a comparative analysis of the technical life cycle of products, the economic life cycle of products and the life cycle of a technology (technological life cycle) embedded in a range of products. The technological life cycle is analysed in terms of its use for achieving the technological forecasting based on the ideality presented while taking into consideration three approaches. This paper displays a set of indicators for assessing the position of a technology considering the life-cycle thereof and subsequently placing it in the category of emerging technologies, developing technologies, mature, or declining technologies, respectively.
KEYWORDS Technical life cycle of the product, product life cycle, life cycle of a technology, technological forecasting

1 INTRODUCTION

The scientific literature [2, 4, 5, 6] shows a number of approaches to product life cycle. Standard SR EN ISO 14040: 2002 states the general definition of the life cycle of a product as "consecutive and interlinked stages of a system-product, from raw material acquisition or natural resources production to post-use of a product" [5]. One approach is the use of life cycle as a marketing concept relevant for the commercial life of the product (product market life) and it describes the development trend of the turnover and profit brought by a product over that period.

Another approach relates to the technical life cycle of a product in close relation to the use-consumption process. Each phase of this cycle is a separate scientific field that has been covered by numerous specialised works. On this basis, one of the most important concepts at work in professional literature, closely related to the Design for Environment, is the Life Cycle Assessment. On this basis, the current design procedure is to determine the characteristics of the products while taking into account the entire life cycle of the product.

Some issues yet are given little consideration, such as the life cycle of a technology and the technological forecasting, with major impact on the evolution and the life cycle of products incorporating that technology. From this point of view, it is very important to determine the position on the curve of life for a particular technology.

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2. ANALYSIS OF THE TECHNICAL LIFE CYCLE, ECONOMIC LIFE CYCLE AND LIFE CYCLE OF A TECHNOLOGY

Considering the products development process, a threefold approach of the life cycle is highly recommendable, including the three aspect that are relevant for designers, such as [4] the technical life cycle or the use / consumption life cycle, the economic life cycle and the technological life cycle.

The technical life cycle or the consumption life cycle (fig. 1) is based on the technical or use-consumption stages of a product, which must be studied and designed by the development team through gathering data about the voice of customers, their needs, their demands, expectations and requirements. According to the specialist literature [1], the technical life cycle or the use-consumption life cycle of a product includes all stages of product achievement [1]:

1. Marketing and market study;

2 Opportunity study and feasibility study;

3. Competitive design for establishing product characteristics and specifications;

4. Functional design based on setting up functions of the product;

5. Conceptual design - product concept;

6. Overall construction design and achievement of the preliminary draft project;

7. Detail construction design which ends up with the final project;

8. Prototyping / zero series, testing;
9. Product supply;
10. Manufacture / production of product;
11. Control, inspection and testing;
12. Marking, preservation, packaging, storage;
13. Marketing and product promotion;
14. Presentation, sales and delivery;
15. Installation, commissioning;
16. Use / consumption of product;
17. Technical warranty, support and maintenance;
18. Remanufacturing of product;
19. Product disposal;
20. Product reuse;
21. Product disposal.

These stages include therefore product development (stages from 1 to 8) and product design that is to be achieved by following the five main stages, namely, competitive design, functional design, conceptual design, overall construction design and detail construction design.

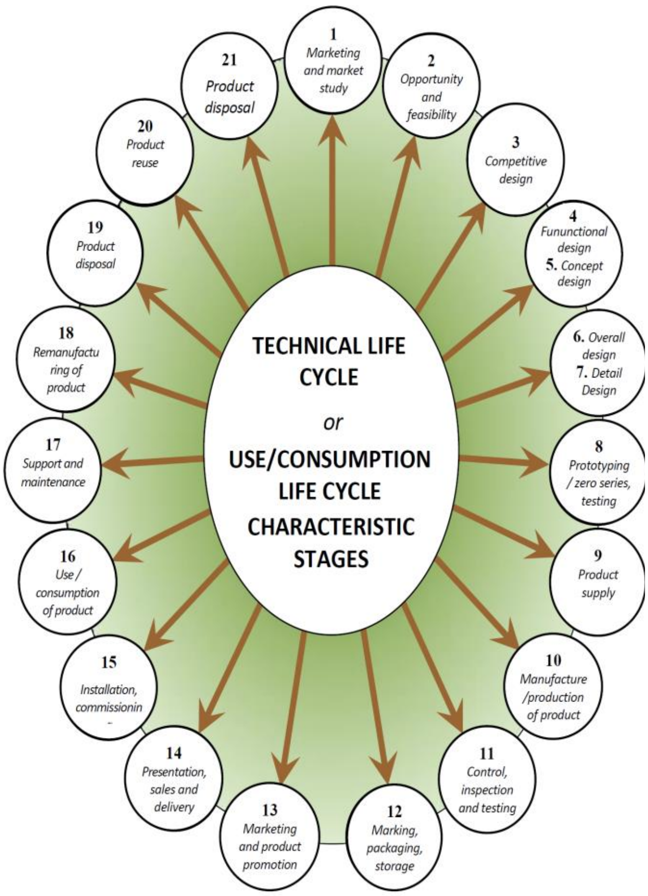

Fig. 1. The technical or use-consumption cycle [4]

The product economic development approach is based on time related financial investments and the benefit obtained by producers, so as to allow planning of continuous product improvement and, finally, planning of product range renewal. The economic life cycle concept has been attributed to Th. Levit from 1965, although it is traceable back to 1950, when it was first introduced by J. Dean.

At present, the economic life cycle is applicable in either the restricted (fig. 2) or extended (fig. 3) approach.

In the restricted or classical approach, what has been taken into account is the time dependence of sales, considering four stages of product evolution on the market (fig. 2): product accession or launching on the market, growth, maturity and decline.

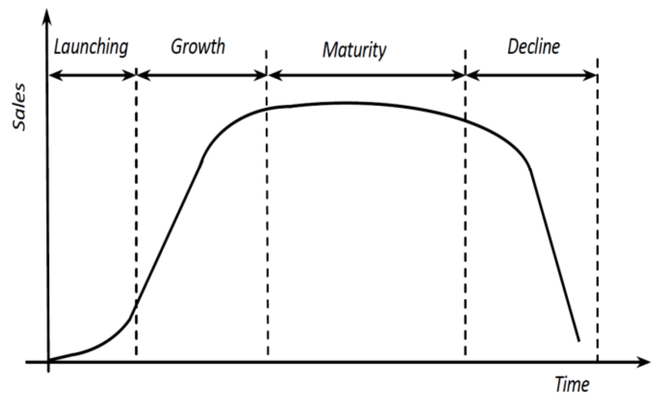

Fig. 2. The classic economic life cycle of a material product [4]

If sales trends were to be correlated according to the lifecycle in figure 2 with the life cycle of the technology that the product incorporates, it can be said that this approach corresponds to indicator 4 of Table 1. A very important issue therefore to be considered is to establish the curve shape for the rest of indicators, the mathematical simulation of these curves and to determine the position on these curves of the respective product and / or technology incorporated therein.

The extended approach (fig. 3) also takes into consideration the pre-market period, when the profit is negative, due to investment in product development and lack of sales.

In this case, the life cycle of a product includes all the stages, covered both during the pre-market period and the on-market period, starting from the stages associated with the development and going on through the production and sales stages, when product launching, growth, maturity and decline take place, respectively, which represent stages that are to be considered in terms of financial aspects and benefits obtained by producers.

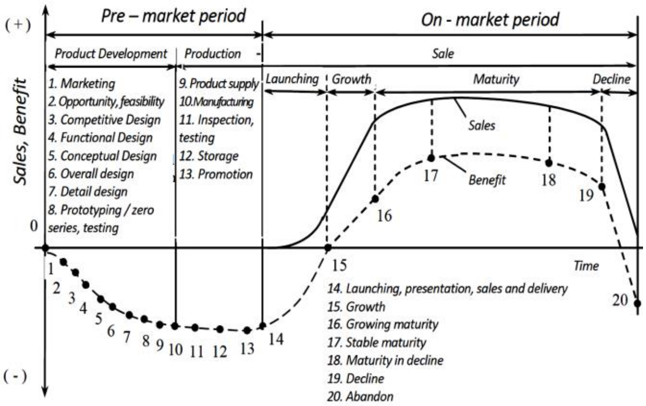

Fig. 3. The extended economic life cycle of a material product [3]

The technological evolution of a product is subject to a similar curve of "S" shape (fig. 4), which can be described, as its life cycle is, in terms of the four characteristic phases, namely conception, or immaturity (emerging technologies), developing or rapid growth (evolution technologies), saturation or maturity (mature technologies) and substitution or aging (decline technologies).

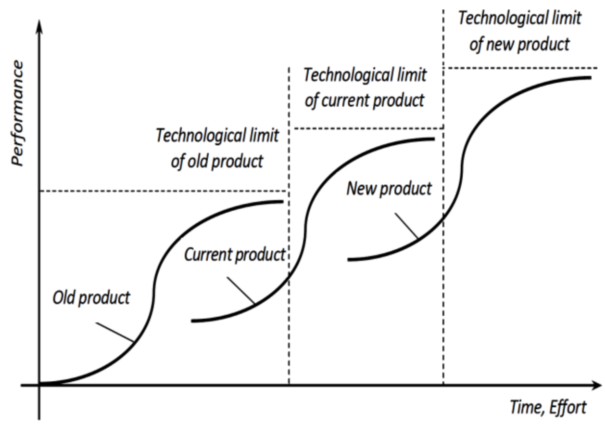

Fig. 4. The technological cycle of a material product [4]

When current technology is at production stage that is during the product maturity period, the development teams work on the new generation of products that incorporate the new technology. The enveloping curve in figure 4 is the rate of technological development, in certain domains. The old technology will co-exist with the new one, but with limited applications. When the development and launching of new technologies are to be considered, the technological forcasting, as well as the evolution trends towards ideality of the systems are applicable [4].

Ideality is a very powerful tool in predicting technology and it can be conceived as the ratio of useful effects and the sum total of costs and harmful effects. To solve any possible issues at the highest level of innovation and for the purpose of technological development, the concept of Ideal Final Result is applicable, which is fixed as a target, which may be a great motivation for specialists.

Application of the Ideal Final Result concept (IFR) is a guide for practitioners, a starting base on which to follow a line of logic technology development without accepting inferior solutions based on compromise. An Ideal Final Result properly formulated allows acting on the conflicting elements, eliminating unnecessary or harmful effects, while the system retains the ability to perform useful functions.

Similarly the following concepts are also definable, such as ”ideal product, ideal substance, ideal process etc.

Ideality can be used in technological forecasting based on three approaches: a narrower/restrected approach using the eight laws of evolution systems stated by Altshuler [1], an extended approach using the 9 classical indicators of ideality [1] and a very detailed approach based on the 31 CREAX trends [7].

In a first approach that is the restricted approach, the system can be evaluated at present moment and development directions can be set using the eight classical laws of evolution systems:

Law no. 1. Law of integrability of system parts: all systems must consist of four parts generically called after the car parts: an engine, a transmission, a control unit and a working unit.

Law no. 2. The law of energy conductivity: For a system to be viable it must ensure the free movement of energy between its parts. This law shows that technical systems develop towards minimizing the energy route within the system (from motor unit up to execution unit).

Law no. 3. The law of harmonizing the system parts operation rhythm: the condition required for the existence of an efficient system is to provide the coordination of the actions periodicity (or natural frequency) of its parts.

Law no. 4. Law of evolution towards the ideal system (unlimited development law of a system): Each system tends towards an ideal system designed as a system with useful functions only without useless or harmful functions or costs.

Law no. 5. The law of uneven development of system parts: the more complex a technical system is, the more uneven the development of its component parts; this development will lead to technical and physical contradictions; system development will continue through solving these contradictions. This law states that various subsystems of the technical system evolve differently (according to their own curves-S), a fact that leads to the development of contradictions within the system.

Law no. 6. Law of system transition to a supra-system: when it has exhausted all its development possibilities, a system attaches to a supra-system totally or through one of its components, so that any further development of the initial system would be performed during that super-system development.

Law no. 7. Law of transition from macrolevel to microlevel: the development of the system working bodies would register an evolution to microlevel, then it will turn down to microlevel. This law shows that systems generally evolve towards fragmentation of their components (primarily effector unit fragmentation).

Law no. 8. The law of the increasing role of the field-substance model, or the increasing dynamism and controllability: the technical systems evolve towards increasing controllability, increase of dynamism and reduction of the extent of human involvement.

The most important of these laws is Law no. 4 which is the primary law of systems evolution. It shows that technical systems evolve towards increasing their Degree of ideality.

Analysis of the current state of the system can be achieved by assigning scores from 1 to 10 for each law, depending on how the system satisfies that law and then providing a graphical display of the results as a radar chart. In order to have a proper technological forecasting, we will analyze the laws (directions) on the diagram with the lowest scores and prepare alternatives of conceptual solutions for the system to better meet that law.

In the second more extensive approach, we can use the 9 indicators of ideality formulated by Altshuler [1]:

1. The degree of dimensionality of the system: evolution 0D → 1D → 2D→3D→complex shapes in space→….→IFR.
2. The system's state of aggregation: evolution solid→liquid→gas→plasma→field→vacuum→…→ IFR.
3. Type, nature and frequency of actions applied on the system: the evolution line Continuous Actions→Vibrating Actions→Vibrating Actions with Resonance Frequency→Stationary Waves→… →IFR.
4. The degree of "porosity" of the system: the evolution Monosolid→Non-homogenious Solid→Solid with Large Size Voids→Solid with Capilar Voids→Porous Material→Dispersed Solid (Micro-millimeter pores)→…→IFR.
5. The degree of dynamic capability of the system: Immobile system→Dynamic system→Multiple joints →Flexible system→High flexible system→Field→… →IFR.
6. Degree of human factor implication: evolution line Man Actuated System→Man Controlled System→Human Interface System→Autonomous System→… →IFR.
7. The system multiplicity degree: the evolution line monosystem→bi-system→polisystem→… →IFR.
8. Nature, tipe and dimensionality of the functions and properties of the system: evolution (Poli)System Monofunction→(Poli)System Polifunction→ (Poli)System Polifunction with opposite functions→… →IFR.
9. The degree of convolution which is estimated through the convolution coefficient and is a measure of the Ideality Degree of a System. The convolution degree may be defined as the ratio of the number of fields and the number of system elements or the ratio between the number of functions and the total number of elements involved in the function.

In this case, analysing the current state of the system, determining the position of the technology used on the curve of life, as well as the technological prognosis can be similarly achieved by using a radar chart or other similar tools.

In the case of the third approach, the very detailed one, the 31 CREAX trends are applicable, either of them conceived as an indicator, quantifiable [7] on a scale from 1 to 10. The most important such indicators are considered to be: Object segmentation, Space segmentation (degree of "porosity"), Surface segmentation, Geometric evolution of linear constructions, Geometric evolution of volumetric constructions, Rhythm Coordination, Action Coordination, Dynamisation, Human Involvement, Controllability, Mono-bi-poly-similar objects, nature, type and dimensionality of system functions, System complexity, Number of energy conversion, degrees of freedom, Smart materials, Density, Macro to nano scale evolution, Asymmetry etc.

In this case also, the approach followed for the state of development analysis and the determination of the future development conceptual solutions may be similar to the first two cases mentioned before.

3. ASSESSMENT OF TECHNOLOGY POSITION BY LIFE CYCLE

To establish a methodology for assessing the position of a technology by life cycle it was first performed an analysis of the characteristics of life cycle stages of a technology, as presented in Table 1.

Table 1. Characteristics of stages of the technology life cycle

Technologies / Indicators	Emerging	Developing	Mature	Declining
1. Buyers' behaviour	A few buyers with high income	The group of buyers is even broader.	Mass consumption. Market saturation.	Buyers remain loyal.
2. Product evolution	Mediocre quality; Lack of standards; Frequent amendments.	Differentiation in quality Good reliability.	Very good quality. Rules respected by all producers.	Lower quality than that of recently emerged competing products.
3. Risks	High	Small, covered by rapid growth.	Small.	-
4. Profit	Small profit with high investments	High	Falling.	Very low.
5. Competitors	Just a fews companies	Many companies with no experience	Price competition.	Decreasing competition
6. Manufacturing	Over-capacity, small series, long labor.	Under-capacity, large series, starting automation	Optimum capacity, high series, optimised costs.	High over-capacity, specialised sales circuits
7. Sales	Very sustained advertising, high costs.	Sustained advertising	Market segmentation, diversifiation. Tendency to extension of the life cycle.	Market re-configuration.
8. Number of products covering the respective technology	Technology incorporated in a single product	Technology incorporated in a few products	Technology incorporated in a large number of products	Old technology coexists in limited applications, with other new technologies that replaced it.

On the basis of Table 1, for determining the position of a technology on the life curve a set of eight indicators is provided, each of which is estimated by calculating the local slope of the curve as shown in fig. 4. Small and positive values on the local slope will show that the technology is in the launching zone. If the local slope has values close to zero, it can be said that the technology has reached maturity. The technology starts to decline when the slope is negative. These indicators are as follows.

I_1 – indicator of the number and behaviour of buyers. This indicator will be measured by the number of buyers whose incomes allow them to purchase a range of products based on the technology analysed. For a limited segment of buyers with higher income the technology can be classified in the category of emerging technologies. If the segment of buyers is larger and includes people with high income surpassing the average per economy, the technology can be defined as developing technology. If the technology is accessible to the majority of buyers, it can be said that it is a mature technology. For technologies in decline the indicator I_1 can be examined from several points of view:

- Producers continue to manufacture and sell the products on a smaller scale to faithful nostalgic buyers;
- Producers continue to manufacture and sell on a smaller scale such products that are already in use;
- Producers continue to manufacture spare parts for owners of old products;
- Holders of certain products (collectionners, technical museums, etc.) use products that are no longer manufactured, wherefore no spare parts are produced any longer (e.g. vintage cars, watches, etc.). In this case, their desire to obtain and use the

components of the goods they own would lead to the developing of new technologies for unique and small series pieces (eg rapid prototyping technologies, high flexible technologies), technologies that will have huge social, economic and technologic implications. These technologies will be the next generation of emerging technologies

Accordingly the indicator I_1 can be expressed in fact through the rate of change in the number of buyers

$$I_1 = \frac{\Delta C}{\Delta t} = \frac{C_2 - C_1}{t_2 - t_1} \quad (1)$$

where C_1, C_2 represents the number of buyers at the time t_1 and t_2, respectively.

When the curve S is expressed through a (continuous) function the result is:

$$I_1 = \lim_{t \to t_0} \frac{C(t) - C_0}{t - t_0} = \frac{dC(t)}{dt} \quad (2)$$

In a similar manner we can proceed to obtain all eight indicators summarized in Table 2.

I_2 - indicator of product evolution. Due to its complexity, this indicator can be broken down into three sub-indicators namely:

I_{21} - sub-indicator of product quality encompassing technology, expressed through the rate of quality evolution K;

I_{22} – sub-indicator of existing standards regarding product, expressed through the rate of change in the number of standards S and

I_{23} – sub-indicator of reliability, expressed through the rate of change in the failure probability F.

The evolutionary technologies make available reliable, differentiated products to consumers. Mature technologies offer the consumers high quality products that are based on rules followed by all manufacturers. Declining technologies provide consumers such products that are lower standards in conceptual and qualitative terms than those incorporating new emerging technologies.

Table 2. Indicators of technology life cycle

Item	INDICATOR	Discrete evolution		Function-based modeling
1.	Indicator of number and behaviour of buyers	$I_1 = \frac{\Delta C}{\Delta t} = \frac{C_2 - C_1}{t_2 - t_1}$		$I_1 = \lim_{t \to t_0} \frac{C(t) - C_0}{t - t_0} = \frac{dC(t)}{dt}$
2.	Indicator of product evolution	Sub-indicator of product quality	$I_{21} = \frac{\Delta K}{\Delta t} = \frac{K_2 - K_1}{t_2 - t_1}$	$I_{21} = \lim_{t \to t_0} \frac{K(t) - K_0}{t - t_0} = \frac{dK(t)}{dt}$
		Sub-indicator of standards	$I_{22} = \frac{\Delta S}{\Delta t} = \frac{S_2 - S_1}{t_2 - t_1}$	$I_{22} = \lim_{t \to t_0} \frac{S(t) - S_0}{t - t_0} = \frac{dS(t)}{dt}$
		Sub-indicator of fiability	$I_{23} = \frac{\Delta F}{\Delta t} = \frac{\emptyset_1 - \emptyset_2}{t_2 - t_1} = -\frac{\emptyset_2 - \emptyset_1}{t_2 - t_1}$	$I_{23} = -\lim_{t \to 0} \frac{\emptyset(t) - \emptyset_0}{t - t_0} = -\frac{d\emptyset(t)}{dt}$
3.	Indicator of risks	$I_3 = \frac{\Delta R}{\Delta t} = \frac{R_1 - R_2}{t_2 - t_1} = -\frac{R_2 - R_1}{t_2 - t_1}$		$I_3 = -\lim_{t \to t_0} \frac{R(t) - R_0}{t - t_0} = -\frac{dR(t)}{dt}$
4.	Indicator of profit	$I_4 = \frac{\Delta P}{\Delta t} = \frac{P_2 - P_1}{t_2 - t_1}$		$I_4 = \lim_{t \to t_0} \frac{P(t) - P_0}{t - t_0} = \frac{dP(t)}{dt}$

5.	Indicator of competition	$I_5 = \frac{\Delta N}{\Delta t} = \frac{N_2 - N_1}{t_2 - t_1}$	$I_5 = \lim_{t \to t_0} \frac{N(t) - N_0}{t - t_0} = \frac{dN(t)}{dt}$
6.	Indicator of manufacturing capacity	$I_6 = \frac{\Delta F}{\Delta t} = \frac{F_2 - F_1}{t_2 - t_1}$	$I_6 = \lim_{t \to t_0} \frac{F(t) - F_0}{t - t_0} = \frac{dF(t)}{dt}$
7.	Indicator of sales	$I_7 = \frac{\Delta A}{\Delta t} = \frac{A_1 - A_2}{t_2 - t_1} = -\frac{A_2 - A_1}{t_2 - t_1}$	$I_7 = -\lim_{t \to t_0} \frac{A(t) - A_0}{t - t_0} = -\frac{dA(t)}{dt}$
8.	Indicator of number of products incorporating the technology	$I_8 = \frac{\Delta T}{\Delta t} = \frac{T_2 - T_1}{t_2 - t_1}$	$I_8 = \lim_{t \to t_0} \frac{T(t) - T_0}{t - t_0} = \frac{dT(t)}{dt}$

Indicator I_2 will result as a weighted sum of the three sub-indicators:

$$I_2 = \sum_{K=1}^{3} q_k \cdot I_{2K} \quad (3)$$

where the sum of weights q is 1.

In the case of the sub-indicator of reliability, once the product evolves, there is a steep increase in reliability. If the reliability is expressed through the probability of failure Ø then attention must be paid to the fact that the evolutionary slope registers decrease of failure probability, due to improved reliability. Moreover, the dependency being reversed, then this ratio must receive a minus sign before the fraction line, if a positive fraction is to be obtained.

The maturity level is characterized by high quality products with norms respected by all producers and also by high quality of products due to the maturity of the applied technologies. But the three parameters that are part of the three sub-indicators no longer have a spectacular evolution and improvements in time take place at reduced rate, almost nul, because the technology has reached its maturity limit.

To establish the formula of the risk indicator I_3 account was taken of the fact that in the case of emerging technologies, there are high risks R, with lower rate of variation, however. Once the technology enters on the slope of growth specific to emerging technologies, the risks get much lower and their decreasing rate (local slope) is very high. At the level of maturity, risks are very low but their rate of decrease is very small. At the stage of decline, risks begin to rise again. In this case also the dependency being reverse, the ratio is considered as negative, in order to make positive the rate of change, in a similar manner to the rest of indicators.

Assessment and quantification of the risks of introducing the new technologies is a particularly complex issue. According to the extended life cycle shown in figure 3, a particularly important issue in this case is to determine the optimal timing for the launching of a new technology. If the latter is launched too early when it is not mature enough, there is a technologic risk related to products reliability, which are based on the respective technology. If the technology is launched too late, there is the risk that competitor companies launch the same technology or similar technologies, with running the risk then that the profits do not cover investments in research-development-innovation that have been carried out during the pre-market period (fig. 3).

The profit indicator I_4 is the indicator that led to the initial construction of the lifecycle. From this point of view, it is desirable for the manufacturers that profits P are as high as possible and, moreover, the profit difference $P_2 – P_1$ between two moments in time and the rate of change in time of the profit is the highest possible. Thus, in the case of emerging technologies, the profit variation rate is very small. At the level of developing technologies, that rate has a steep rise; at the maturity level, the profit remains nearly constant, due to price competition; when the technology starts to decline, profits start to fall and the change rate (slope) is negative.

A particularly important indicator in determining the position of a technology life cycle is the competition indicator I_4 that can be expressed as the rate of change in time of the number of competing companies *N*. Emerging technologies are characterized by a very small number of companies, mainly due to intellectual property rights and the high price of patents. At the same time, the evolution in time of the number of companies during this period it is slow, so the local slope is very small. For the emerging technologies, the number of companies starts to grow rapidly, yet most of the emerging competitors lack experience. For such technologies, the rate of change in the number of companies is very high. At the level of maturity price competition appears and the number of companies using a certain technology is relatively constant; as a consequence, the rate of change in the number of companies has values close to zero. In the case of the decline technologies, the number of companies starts to decrease, so that the local slope becomes negative.

The indicator of manufacturing capacity I_5 is also an important indicator. For the market launch of new products based on new technologies, the companies generate or assign a manufacturing capacity *F*. In the case of emerging technologies, since the product is manufactured in small series, absorbing a large amount of labour, companies fail to capitalize at an optimal level the generated manufacturing capacity, with manufacturing overplus capacitys being an outcome.

At this phase, the flexibility of manufacturing means has an important part to play enabling the companies to make a rapid shift from one production task to another, which is required in the case of frequent technological changes. As the technology reaches the developing level, the manufacturing series increase, the manufacturing capacity is valorised to the maximum and a pessure sets in to continuously increase the manufacturing capacity. Therefore the growth rate of the manufacturing capacity that is the local slope is great. Due to large manufacturing series, while increasing manufacturing capacity, automation is brought in as well. When technology grows mature and the trend is towards mass production, they put a particular emphasis on the manufacturing capacity improvement and cost optimisation. Production is stable and there is no need to further increase the manufacturing capacity so the rate of change of the manufacturing capacity comes close to zero. For declining technologies again the manufacturing capacity starts to be no longer fully exploited because the manufacturing series are reduced and therefore the pressure appears for the company to reduce its manufacturing capacity and to relocate it with a view to developing new technologies embedded in new products. Thus, the rate of change (local slope) is negative in this sense.

The market sales indicator I_7 can be also taken in account when we intend to assess a technology in terms of its life cycle. One way to assess this indicator could be the costs *A*, with the promotion of products incorporating the technology and their variation in time that is the costs registered at two moments in time $A_1(t_1)$ and $A_2(t_2)$. For the emerging technologies the costs are high, but relatively constant over time, as they are sustained by commercials on the products. As technologies start evolving, the advertising costs shall be progressively diminished, at a high rate and therefore, due to reverse dependence, the minus sign shall be used before the fraction of indicator I_7 in Table 2. The following occur at the maturity level: market segmentation, product diversification, tendency towards life cycle extension, while promotion costs are low and kept constant over time, so that their rate of change (local slope) is practically null. When the technology starts to decline, promotion costs gradually decrease.

A very important indicator is the indicator showing the number of products incorporating a certain technology I_8. At first, an emerging technology is incorporated into a single product. As the technology develops to maturity, the number of products T incorporating that technology starts growing rapidly. At the maturity level, a limitation in the number of products is reached, so the variation rate is virtually nul; when the technology starts to decline, the rate becomes negative, due to the gradual reduction in the number of products incorporating that technology and its replacement by a new one. In most cases the old technology coexists with new technology, yet only for limited applications (e.g. even if jets developed, propeller planes are still used on a narrow scale; even if electric trains are generally in use nowadays, steam trains are still used by tourists etc.).

On the basis of eight indicators defined above, the global indicator, which allows us to assess the position of a technology on the life curve at a given moment in time t_0 can be calculated as a weighted sum of these indicators.

$$I = \sum_{K=1}^{8} I_K \, P_K \tag{4}$$

where P_k – represents the weights that meet the condition:

$$\sum_{K=1}^{8} P_k = 1 \tag{5}$$

4. CONCLUSION

Based on comparative analysis of the economic life cycle (classic and extended; the technical life cycle, as well as the technological life cycle), the paper proposes an assessment methodology of the life cycle position of a technology based on a global indicator calculated as the weighted sum of several partial indicators, which mathematically are the local slopes of curves *S* for a certain moment in time. The technological cycle of life can be used to make technological forecasting based on ideality as presented in three approaches: (i) the eight laws of systems evolution set up by Altshuller; (ii) the classic indicators of ideality and (iii) the 31 CREAX indicators for assessing ideality. It has been assumed that the methodology is useful in product and system development on the basis of technological forecasting.

5.ACKNOWLEDGEMENTS

This work was financially supported through the project "Routes of academic excellence in doctoral and post-doctoral research - READ" co-financed through the European Social Fund, by Sectorial Operational Programme Human Resources Development 2007-2013, contract no. POSDRU/159/1.5/S/137926.

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