TREEOR Model: An Approach to the Valuation of Intellectual Capital

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Abstract: Following the biological behaviour of a tree and its growth system, this paper proposes a model of valuation of the Intellectual Capital of an organization based on a variation of the classical Lotka-Volterra equations system. The proposed model explains the growth of an organization as a consequence of its Intellectual Capital (increment of the surface of the roots), its Knowledge (the consumption of nutritious) and its Learning (fertility of the floor). And based on the proposed model, an example with real data is given.

Keywords: Intellectual Capital, Organizational Learning, Knowledge Management, Lotka-Volterra system.

1. Introduction

Nonaka and Takeuchi (1995) define an analogy as being halfway between the imagination and logical thought. The definition of concepts through analogy is one of the fundamental steps in the construction of new theoretical perspectives (Kaplan, 1964; Tsoukas, 1991; Van de Ven and Poole, 1995). In this way, we study the analogy that exists between trees and organizations, explaining similarities and differences between them and proposing a model for the valuation of Intellectual Capital based on an analogy already mentioned previously in the literature: G.E.S.T (1986) with their "bonsai tree" about the idea of technology; Edvinsson (1997), who made use of the metaphor of a tree to define the Intellectual Capital concept; Giget (1988) with their tree of company competitions; Viedma (2002) which represents the OICBS system; or GIDE (2002), which identifies each managerial "occupation" as a type of tree.

The proposed model tries to measure the length of the roots or Intellectual Capital (IC) of an organization and incorporates a bifurcation parameter that values the growth according to the capacity that the organization has to increase their IC. In turn, the roots are responsible of the absorbing nutrients or Knowledge, generating two kinds of Knowledge flows: those with aims of consumption for growth (Explicit-conscious) and those whose dimension is the regulation or maintenance of the Tree-organization (Implicit-automatic). The Knowledge absorption depends, to a great extent, on the type of soil or Learning that it has. Finally, we try to value the speed with which the Knowledge reaches every part of the Tree-organization.

The paper proceeds as follows. In section 2., we explain the key elements of the tree analogy with the organization; section 3., reflects the contents from the classical Lotka-Volterra model and straight off, in section 4., we explain the proposed model: starting from a system of differential equations, and using the Runge Kutta method of the Mathematica program, we try to recognize the organizational mechanism of growth in analogy with the growth of a tree. In section 5., we generate the discussion and to finish, in section 6. we study the Bankinter case.

2. Tree-organization: Elements of the analogy

The model of Tree-organization or TREEOR model presents the following elements: Intellectual Capital, Organizational Learning and Knowledge.

2.1 Intellectual Capital

The concept of roots or Intellectual Capital follows the proposed definition by Euroforum (1989), where their key elements are: Human Capital, Structural Capital and Relationship Capital.

Human Capital is made up of competences (knowledge and abilities) and attitudes (such as loyalty, flexibility, etc). The essence of this capital survival, that is the *core competence* which provides, goes through the stimulation,

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retention and appropriation of the benefits which brings the existence of people with managerial talent, technological knowledge, etc. According to Milgrom and Roberts (1993), the organization should centre their attention on reducing the mobility as an incentive to the investment in the specific human capital. Although the real important thing, is to capture the best of each person so that it doesn't disappear, and in case of replacement, the cost is low (Kay, 1994).

Structural Capital is divided in Organizational Capital (Organizational Routines) and Innovation Capital. Inside the Organizational Capital, the routine concept is framed as a "complex model of behaviour, unchained by a number of former incentive, working automatically and as an unit" (Winter, 1986). These organizational routines are the previous step to the accumulative learning of the organization, because the repetition of the these is done with the objective of obtaining success (Gavetti and Levinthal, 2000). On the other hand, the Innovation Capital is shaped by the formalized and protected (patents) knowledge of innovation. That knowledge protection tries to keep them safe from competitors and this way, provide competitive advantages to the organization (Teece, 1990).

Finally, the objective of *Relationship Capital* is the creation and maintenance of the relationships that the organization has with its environment. Starting from the affectionate communications between company and environment, intangible actives are born outstanding as the reputation, or the alliances (essential for strategy success).

2.2 Organizational learning

The soil fertility is its own capacity to supply all and each one of the nutrients that the tree needs at that moment, quantity and appropriate form. The following factors influence on the soil fertility: type of crop, climatology, cultural practise and soil texture (quantity of clay). If we make an analogy between soil fertility and organizational learning, and following Fiol and Lyles (1985), we will find these similarities: Strategy, Environment, Culture and Structure respectively.

Strategy: for elaborating the organizational strategy, several factors converge: from the environment, giving rise to a deliberate strategy, that is to say, "the circumstances of the moment, the events that arise from the environment, lead to the abandonment or revision of strategic elections, although, firmly wanted" (Strategor, 1993); to the memory on which learning is based, this is, "in the exchange of ideas, knowledge and mental models [...] and it's based on the previous experience" (Stata, 1989). Senge (1990), maintained that "our mental models not only determine the way of interpreting the world, but also the way of acting", so that, every organizational behaviour, as a result of a strategic application, goes through a mental models lattice that form distorted perceptions of the reality.

Environment: climatology (in terms of fertility of the soil) where a Tree-organization lives, influences directly in the learning behaviour of this one. "An organization that learns is an expert organization in creating, acquiring and transmitting knowledge, and in modifying its behaviour to adapt itself" (Garvin, 2003). That necessity of adaptation on continual improvement, of survival, is intimately related with the environment where the organization competes. It is such, that depending on the stability or dynamism of the environment, the learning is modified. A stable environment can restrain the development of the organizational learning (Lant and Mezías, 1992; Fiol and Lyles, 1985), while a dynamic, unstable and highly competitive environment, causes organizations more capable when developing its learning capacities, as well as more active for the acting of sustainable competitive advantages that allow its survival.

Culture: it defines how manhood is identified with the organization, and how he conceives his system of values and relates it with his own (de Val, 1994). It is an accumulation of answers that the organization has learned in view of raised problems (Schein, 1988). The question lies in how the culture is detected and the consequences that it implies for the organization development in a unsettled environment. The organization survival requires its capacity of adaptation or transformation that will depend on the organizational learning processes.

Structure: According to Strategor (1995), "structure is a group of functions and relationships that determine the tasks that each organization unit should complete formally and the ways of collaborating among them". The relationship between strategy and structure, is characterized by the existence of a complex component in which variables such as the environment take part in it, and the capacity of transmission in the management activities (culture). The behaviour of the organization, has a permanent movement of sorting its structure, that is to say, the change dynamics causes a continual evolution for the sake of its survival: "foreseen and systematic process which is carried out to change the culture, systems and organizational behaviour, to improve the effectiveness in solving their problems and for the objective attainment" (Lippit, Langset and Mossop, 1989).

2.2.1 Types of organizational floor

Which are the most appropriate soils for the growth and root fortifying (Intellectual Capital) of the Tree-organization? There are three soil classifications to study: (a) Sandy: characterized by its great permeability. These are soils that, due to their scarce retention, they present a huge poverty in nutrients (knowledge); (b) Clayey: tendency to be flooded and to suffocate the roots (Intellectual Capital). Their main characteristic is its wealth in nutrients (knowledge); (c) Mix: appropriate for most crops, susceptible of improvement and with intermediate characteristics between the sandy and the clayey ones.

Now then, how can we identify each one of these types with the current organizational structures? Let us analyze each one of them:

a) Sandy: it has a great communication channel, where the whole knowledge of the organization could flow satisfactorily, but it moves in a simple environment, where the processed information isn't valued nor understood as a competitive advantage. These are companies that do not learn and do not negotiate with effectiveness the acquired experience.
b) Clayey: the knowledge of the organizational structures that lives on this type of soil is remarkable. The great inconvenience is its inefficacy when processing it by its roots, that is to say, the Intellectual Capital is unrecognizable, replaceable and identifiable with difficulty, due to a structure that suffocates the intangible ones.
c) Mix: it's the desired structure for the organization, where the channels provide the knowledge flow, the permeability provides nutrients for its survival and the Intellectual Capital secures the growth and the flow of the organizational knowledge increases.

2.3 Knowledge

Nonaka (1994) clearly summarizes the actual importance of knowledge: "in an economy where the only certainty is the uncertainty, the best source to obtain lasting competitive advantage is the knowledge." The knowledge is the source of life of the Tree-organization, but its reception needs of a root lattice (Intellectual Capital) depending on certain conditions of the soil. The fertility of this one will provide a larger bifurcation of the roots, that in turn will increase the knowledge flow and in consequence, the survival and the growth of the organization will be larger.

Nonaka (1994), offers an idea of company innovating, founded on ideas and ideals, and whose existence is based on the creation of knowledge: "creating new knowledge means literally to recreate the company and each one of the people who work in it by means of an uninterrupted process of personal and managerial remodelling".

Authors such as Huber (1991), Nevis *et al*. (1995), or Winter (2000) have tried to agree on the process of organizational learning, bringing forward key concepts of the essential stages of this. Within the idea of Knowledge Acquisition, two supply channels coexist: internal and external. The internal development of knowledge, follows a process of essential competitions, heroines in the cases of assumption and assimilation of irreversible decisions in the past, as well as in the absence of flexibility in the adaptation to the change (Leonard-Barton, 1992). However, while the external acquisition of knowledge, makes use of contractual mechanisms that define the knowledge

and protect it from the effect "benchmarking", the knowledge apprehension from the environment, uses the relationships between staff, clients and suppliers.

3. A basic model of Lotka-Volterra

The Lotka-Volterra Model studies the interactions between two species, the depredator and the prey and it has the following characteristics: a) preys are the only source of feeding for depredators; b) it explicitly includes the dependence of the species of preys of population density; c) there is no emigration or immigration phenomena.

The model was independently developed by Lotka (1925) and by Volterra and it is developed by the following differential equations system(1926):

$$\dot{H}(t) = r \cdot H(t) - A \cdot H(t) \cdot P(t)$$

$$\dot{P}(t) = B \cdot H(t) \cdot P(t) - m \cdot P(t)$$

where $\dot{H}(t) = dH(t)/dt$ and $\dot{P}(t) = dP(t)/dt$. The interpretation of these two equations is explained by the following parameters: *H(t) = density of prey; r = intrinsic rate of prey population increase; B= reproduction of predators per 1 prey eaten; P(t) = density of predators; A = predation rate coefficient;* and *m = predator mortality rate.*

From Lotka-Volterra classical Model, Moráveck and Fiala (2004), an applicable version of the biological systems is carried out and they include another equation in the system. This way, the constant parameters of the classical model become functions of the following type in the proposed model that we will explain in the next section:

$$A = A(t) = b \cdot \alpha(t)$$

$$B = B(t) = b \cdot \left[d - \varphi(t)\right] \cdot \alpha(t)$$

4. The proposed model: TREEOR

We have formulated a model that supports the idea of growth and survival of the Tree-organization according to soil fertility where it's located (learning), which will provide a larger or smaller accessibility to the nutrients (knowledge) and in consequence, the sustainability to the soil of the roots (intellectual capital) will determine the survival of the tree. As we have previously seen, and following Moráveck and Fiala (2004) in analogy with the organization, we present an empiric formulation based on a Lotka-Volterra equations system (table 1).

Table 1: Description of the TREEOR model variables.

Parameter	Variable name	Description
$\Lambda(t)$	Root length	Intellectual Capital (IC) measured according to the last bifurcation of the corresponding root.
$\alpha(t)$	Bifurcation parameter	It values the growth according to root branching of the tree-organization, so that the smaller ramification capacity (creation of value-IC), the smaller absorption of nutrients (knowledge) and in consequence, a slower growth.
$\Phi(t)$	Nutrient flow: knowledge	Quantity of knowledge in movement, differentiating between consumption aim for the growth (Explicit-conscious) and whose dimension is the regulation or maintenance (Implicit-automatic).
$\varsigma(t)$	Knowledge supply speed	Speed in which the Tree-organization supplies the knowledge to every part of it and it allows its absorption from the roots (Intellectual Capital).
a, b, c, d, e, f, g	Dynamical parameters	

The formulation (1), shows the behaviour in the root length with regard to the speed of nutrients supply. So, we try to study the growth of the organization according to the

grade in knowledge absorption on behalf of the Intellectual Capital (IC):

$$(1)\quad \dot{\Lambda}(t) = a \cdot \Lambda(t) - b \cdot \alpha(t) \cdot \varsigma(t) \cdot \Lambda(t)$$

$$\dot{\varsigma}(t) = b \cdot [d - \Phi(t)] \cdot \alpha(t) \cdot \varsigma(t) \cdot \Lambda(t) - c \cdot \varsigma(t)$$

$$(2)\quad \dot{\alpha}(t) = \frac{e}{\Phi(t)}$$

The equation (2) tries to value which would be the bifurcation parameter of the root balance or Intellectual Capital because, according to the last of the bifurcations, we will measure the length of the roots. So we can extract a polarity: (i) a longer length of the roots or Intellectual Capital, a larger growth speed of the Tree-organization; (ii) a larger length of the roots (IC), a slower speed of nutrient or knowledge supply.

Starting from Moráveck and Fiala's (2004) empiric definition about nutrient flow, we assume that:

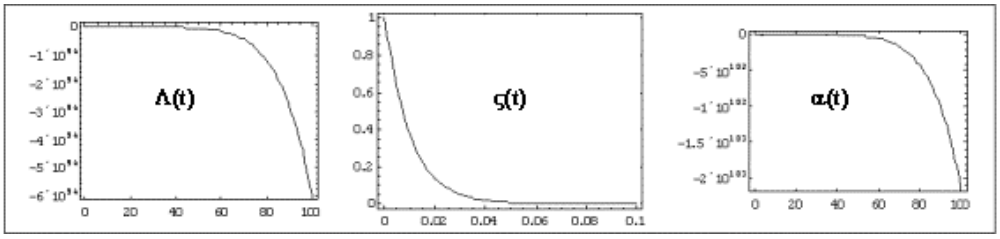
$$(3)\quad \Phi(t) = f \cdot \Lambda^2(t) - g \cdot \Lambda^3(t)$$

5. Discussion

The system of equations (1)-(3) has been solved by Runge Kutta's method of Mathematica program, version 4.0.1.0. For the resolution and interpretation of this model, we will study a simulation of their dynamical parameters, starting from a non trivial initial solution: *a* = 1; *b* = 1; *c* = 100; *d* = 2.5; *e* = 1; *f* = 2; *g* = 0.1.

We start from an initial situation (table 2), where the root length as well as nutrient speed supply, diminish intensely. This is, if the capacity of the organization to create value or IC decreases, then it will have fewer tools to absorb the knowledge and in consequence their global growth will be slower. Besides, if the speed of knowledge supply diminishes, fewer nutrients enter each time, and the IC is held back.

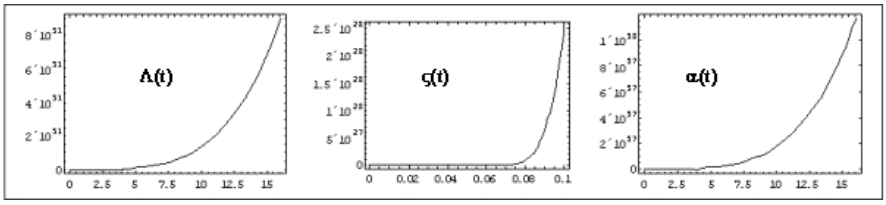
Table 2: Graphic behaviour of the variables: Length of roots or IC, Knowledge Supply Speed and Bifurcations Parameter, respectively



How do each of the variables behave before parameter changes? We will begin carrying out a small variation on the parameters *a* and *b*, responsible for the variations in the root length or IC and of the speed supply.

The table 3, presents an important situation for the Tree-organization: the intellectual capital of the company grows because it has the necessary capacity to increase its intangible and in this way absorb the knowledge and give it efficiently to every part of the company. What does the quantity of knowledge depend on what takes over the organization and allows it to grow? The fertility of the soil on which the organization is influences in the quantity of nutrients that are absorbed, that is to say, the organizational learning allows a larger takeover of knowledge.

Table 3: Graphic behaviour of the variables: *a* = 53 and *b* = 53

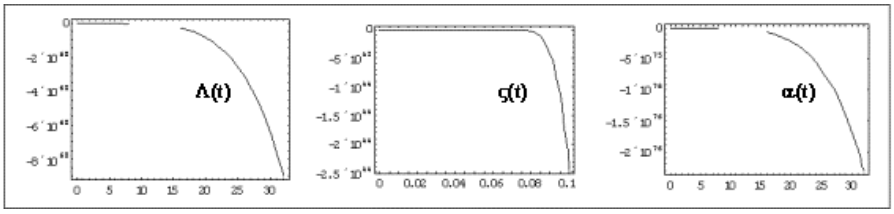


What is learning translated into?: Strategy, Environment, Culture and Structure. This group of elements represents the fertility for the organization growth. Now then, the way in which the four pillars of the learning combine, gives rise to different soils: sandy, clayey and mix. In table 3, the organization soil is mix, because it

expedites the knowledge absorption by administrating an appropriate intellectual capital.

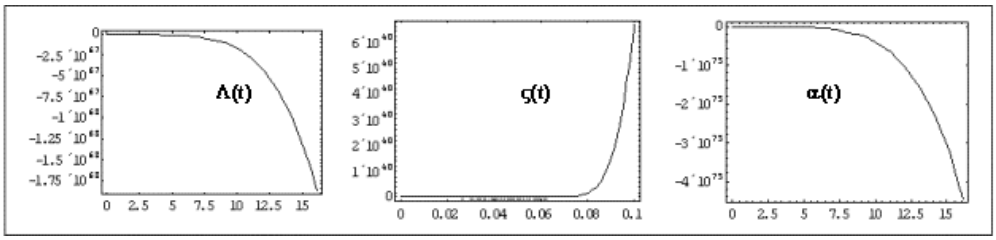
According to Garvin (2003), the organization that learns is an expert in five activities: systematic resolution of problems, experimentation of new focuses, use of their own experience and of the past to learn, learn from experiences and more appropriate practices of the other companies (benchmarking), and in transmitting quick and efficiently the knowledge to the whole organization. The simulation of table 3 reflects a mixed learning on which a company is settled which knows how to negotiate their human, relationship and structural capital, as well as their knowledge.

Table 4: Graphic behaviour of the variables: *a* = 53, *b* = 53 and *e* = 3



Let us suppose now that, about the simulation of table 3, we carry out a change in parameter *e*. This is, we vary the length of the roots, the knowledge supply speed and the parameter of bifurcations. What happens now to the learning? In table 4, we have the answer: grow and absorbing knowledge is stopped. The soil is infertile because it is a sandy soil that it does not retain knowledge. We would be faced with a permeable learning; the organization possesses IC but the soil on which it is settled does not favour the absorption of knowledge and in consequence stops growing.

Table 5: Graphic behaviour of the variables: *a* = 53, *b* = 53, *e* = 3 and *c* = 200



The companies with a sandy learning live a stable environment (Lant and Mezías, 1992; Fiol and Lyles, 1985) that obstructs the growth of their IC and ignores the importance of the intangible such as the culture. "The ability of learning more quickly than competence is nowadays the only sustainable competitive advantage" (De Geus, 1988), and it hopelessly goes by the organizational pillars that provides the culture. And if we carry out a new variation on the previous simulation (table 4)? On this occasion (table 5), we vary lightly the knowledge supply speed and we observe an interesting behaviour: in spite of the growth of knowledge speed, the organization stops growing. This is a case of clayey learning because the company does not negotiate the knowledge. The IC becomes flooded and it cannot grow, it absorbs knowledge but it does not know what to do with it, it does not learn and it also oppresses its intellectual capital.

6. Numerical example: Bankinter case

In this section we present a numerical example of the proposed model, using data from Bankinter, a Spanish Industrial Bank which was founded in June 1965 through a joint venture by Banco de Santander and Bank of America. Bankinter has ranked 107 when it was founded and is currently among the top six Spanish banks.

We are interested in the behaviour of Intellectual Capital variables of Bankinter in two periods of time. The first period is from 2001 to 2003 and the second one is from 2002 to 2004. We have used data from Bankinter Annual Report and we have identified the variables of our TREEOR model with Bankinter indicators of Intellectual Capital (Table 6).

Table 6: BANKINTER indicators for the numerical example of TREEOR model

TREEOR variables	BANKINTER indicators
$\Lambda(t)$	Percentage of solved economic incidences in 48 hours (%)
$\alpha(t)$	Contribution to GDP per employee (in thousands of euros)
$\Phi(t)$	Internal job rotation (%)
$\varsigma(t)$	Percentage of employees who meet or exceed their targets (%)

Following the same way for resolution the simulations of TREEOR model, we have solved the equations system by Runge Kutta's method of Mathematica program, version 4.0.1.0. But, in this case we will analyse the model through real data from Bankinter case (table 7).

Table 7: Real data from Bankinter.

TREEOR	2004	2003	2002	2001
$\Lambda(t)$	85,26	82,64	78,38	75,00*
$\alpha(t)$	134,65	150,90	121,61	106,81
$\Phi(t)$	28,80	27,71	17,65	23,61
$\varsigma(t)$	48,71	83,43	29,31	62,27

(* they are not available data of this year, so we have approximated it through known data of previous years)

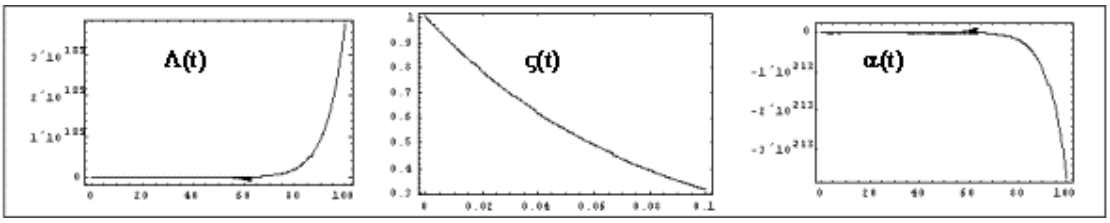
According to the previous values and solving the equations system of the proposed model, an estimation of the parameters *a, b, c, d, e*, *f* and *g* have been obtained (table 8).

Table 8: Parameters of the TREEOR model in Bankinter case

Parameters	Period 2001-2003	Period 2002-2004
a	0,0651	0,0633
b	0,0000	0,0000
c	12,1417	-8,1646
d	505,5661	-246,5072
e	6441,8010	3654,9810
f	1,0000	1,0000
g	0,0123	0,01250

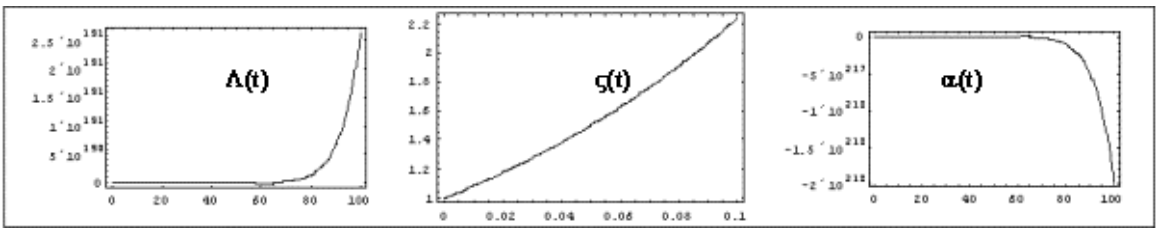
In the first period (2001-2003) we can observe how the Intellectual Capital or length of the roots grows and the Knowledge supply speed diminishes (table 9). At the same time, the bifurcation parameter starts to decrease. It means that the company has a great Intellectual Capital Structure, which gets knowledge from the soil or Learning Structure. Bankinter is an interesting case of learning organizations where its bifurcation parameter diminishes when the Intellectual Capital increases. The Bankinter soil is very close to mix learning because the communication channel of knowledge exists and the structure of Intellectual Capital is developed.

Table 9: Graphic behaviour of the variables in the period 2001-2003 (Bankinter): Length of Roots or IC, Knowledge Supply Speed and Bifurcations Parameter, respectively



The bifurcation parameter does not grow as the Intellectual Capital due to Bankinter has not found its equilibrium parameter of "new knowledge" in this period. That is to say, $\Phi(t)$ is the resulting part of the whole knowledge that is not used in maintenance actions (equation 2), and every organization must know what is the quantity of "new knowledge" that it can process.

Table 10: Graphic behaviour of the variables in the period 2002-2004 (Bankinter): Length of Roots or IC, Knowledge Supply Speed and Bifurcations Parameter, respectively.



In other case, the knowledge which is absorbed and it is not processed, causes reductions in the knowledge supply speed. In the second period (2002-2004) (table 10) we can observe how Bankinter gets its right bifurcation parameter which allows it to reach a higher level of knowledge supply speed (it increases) and in consequence, the Intellectual Capital increases too due to a great management channel about intangible values.

The TREEOR model, tries to value the responsible elements for the firm growth, and presents the knowledge as indispensable food and the intellectual capital, as the absorption tool. Mentioning the classical model of Lotka-Volterra, we would be speaking about the depredator (IC) and the prey (Knowledge). Now then, the place where the hunt takes place is vital, because it is not the same to speak about sharks and fish than about cats and mice, that is to say, the soil on which the absorption of Knowledge is developed influences greatly on the growth and organization maintenance. It seems that, the Learning is responsible for the larger or smaller Intellectual Capital creation of the organization.

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