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Organizations are Control Systems

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Abstract: For more than forty years, the literature on organizations and firms considered as cybernetic systems is rich in authors who favour this interpretation (Kast and Rosenzweig, 1972; Beer, 1981; Jackson, 1993) as well as in texts that affirm the difficulty if not the impossibility of considering organizations as cybernetic systems (Tannenbaum, 1972, Sutherland, 1975). This paper belongs to the first group. It is clear upon observation that organizations are cybernetic systems not only from an interpretative theoretical point of view but also due to their intrinsic nature as self-regulating systems. To better demonstrate how they carry out their regulation, we consider the organizations-firms as Control Systems. We are convinced that in order to remain vital for a long period of time in a perturbed environment, organizations – in particular, firms – must undertake control activities regarding their organizational, economic and financial variables. This theoretical study holds that organizations-firms “are” Control Systems that can survive “only if” their management can achieve the vital objectives set by the stakeholders. Since the entire chain of control is inside the system, and management is part of the same control structure, organizations-firms can be “intrinsically” – and not only representatively-speaking – conceived of as control systems even from various points of view: 1. as autopoietic systems, following Maturana and Varela’s conception; 2. as teleonomic systems, following Monod’s conception; 3. as viable systems, following Beer’s conception; 4. as systems of efficient transformation, following Mella’s conception; 5. as cognitive, intelligent and explorative systems; 6. as multi-objective and multilevered Control Systems of performance.

Keywords: Organizations as Cybernetic Systems, Organizations as Viable Systems, Organizations as Control Systems, Organizations as Systems of Efficient Transformation, Organizations as Cognitive Systems

Introduction. Organizations and Firms as Cybernetic Systems

MANAGING THE TOUGHER and faster dynamic changes in the environment has been the main competitive challenge for firms in recent decades. Firms have experienced the not so easy task of adapting to these environmental changes by acquiring superior dynamic capabilities (Teece et al., 1997) based on both distinctive resources (Rumelt, 1984) and knowledge management (Grant, 1997). Struggling for survival has turned into a continual learning process in order to adapt and self-renew both products and processes as well as the overall organizational structure (Volberda and Lewin, 2003).

Stemming from the perspective on organizational structure change, for more than forty years, the literature on organizations and firms considered as cybernetic systems has been rich in authors who favour this interpretation (Kast and Rosenzweig, 1972; Beer, 1981; Jackson, 1993) as well as in texts that affirm the difficulty if not the impossibility of consid-

ering organizations as cybernetic systems (Tannenbaum, 1972; Sutherland, 1975; Morgan, 1982).

This paper belongs to the first group. We are convinced that by nature organizations can adapt and thus survive environmental changes thanks only to the control systems that regulate their existence and, for this reason, they *are* “control systems”. There are two main reasons for these arguments (Jackson, 2001). First, the systemic approach overcomes the boundaries of a single discipline, which is generally used to tackle problems, thereby promoting an interdisciplinary approach. Second, the cybernetic view puts forward an holistic approach aimed at countering the reductionistic view. Reductionism focuses on the components’ functioning, instead of on investigating the overall (systemic) functioning. Organisations as systems show emergent behaviours, which are starkly different from the sum of the components’ behaviour. Furthermore, cybernetic approaches to management are widespread and successful, too; for instance, cybernetics has been applied to both strategy (Warren, 2004) and decision-making (Robb, 1984).

For this reason, even without recourse to the metaphor of mechanistic organization, which stands opposite to the organistic/organic one (Burns and Stalker, 1961), and recalling Norbert Wiener’s statement that Cybernetics is the science of the study, design and simulation of “control and communication in the animal and the machine” (Wiener, 1948), we hold that “organizations” due to their intrinsic nature as self-regulating systems can in fact be observed as cybernetic systems (Ericson, 1972) that are self-controlled in order to remain vital and carry out the processes for which they were created.

The objective of this paper is to identify a cybernetic framework for organizational structure design that enables firms to better cope with and adapt to fast environmental changes. A theoretical model will be proposed and empirical examples will be developed in order to apply the theory to the practice.

To better demonstrate how they carry out their regulation, we shall consider the organizations-firms as Control Systems in which the individuals forming the organizational structure are an integral part of the “chain of control”.

In the next section a review of Control System theory and the main systemic approaches to organizational structure design will be outlined. The third section introduces the cybernetic model of the firm as well as some empirical applications. In the fourth section a comparative discussion on the control properties shown by each model reviewed in section 2 will be proposed. Concluding remarks and directions for further research will be given in section 5.

Literature Review

Control Systems

Considering the following concise definition of control problem proposed by Michael Arbib:

In general terms, therefore, a control problem is to choose the input to some system in such a way as to cause its output to behave in some desired way, whether to stay near a set reference value (the regulator problem), or to follow close upon some desired trajectory (the tracking problem) (Arbib, 1987)

we define a variable Y_t as “controllable” if, on a temporal, discrete or continuous scale, $t=1, 2, \dots$, we can assign it a given value Y^* (set-point) which can represent an objective, goal, constraint, or limit of Y_t .

If $Y_t \neq Y^*$ we can measure a distance or variance or error, which we denote by $E(Y)_t = Y^* - Y_t$.

We define X_t as a control variable which determines the values of Y_t according to a causal relation (defined by some process or apparatus), so that, by acting on X_t , we can produce a dynamics for Y_t that tends toward Y^* .

We define as a Control System any set of apparatuses, logical or technical (algorithm or machine, rule or structure, etc.) that, for a set of instants, perceive $E(Y)_t$, calculate and assign the values X_t , and produce the appropriate Y_t to gradually annul, when possible, the error $E(Y)_t = Y^* - Y_t^*$ at instant t^* .

Without going into detail about the history of systems thinking, here is how Norbert Wiener masterfully presents the idea and the function of both “distance” – that is, error – and the technical structure subject to the control.

[...] in order to perform an effective action on the external world not only is it essential to have good motor organs but the actions of such organs must be adequately reported to the central nervous system for control purposes, and the readings of the control organs must appropriately combine with other information from the sense organs in order to determine a regulated motor output (Wiener, 1968: 30).

Since, in fact, the system “perceives and evaluates” its variance from the objective, a typical feedback control is carried out.

The Control System is repetitive and functions by means of action (X acts on Y) and reaction ($E(Y)$ acts on X through Y); with a certain number of iterations on the control lever, it tries to achieve the objective (goal-seeking systems) or to respect the constraints or limits (constraint-keeping systems).

Among the various possible models, we chose to represent (in more detailed form) the simple logic of control according to the standard model of the Control System in fig. 1, which clearly shows that in Systems Thinking terminology a Control System is nothing other than a balancing loop where the values of X_t – which determine Y_t in the direction “s” (“same”) – do not depend on Y itself but on the error, $E(Y)_t$, in the direction “s” (the higher the error, the greater the corrective intervention of the X). It is clear that the higher Y_t is, the less the variance is; for this reason there is a relation in direction “o” (“opposite”) between Y and $E(Y)$.

The variable X_t (or, if more than one, the vector $[X]$) is also defined as the action variable, the control lever, or the active variable. If $[X]$ is composed of N action variables, the system is called a multi-lever control system.

The variable Y_t (or vector $[Y]$) is also defined as the controlled or passive variable. If $[Y]$ is composed of M variables, the system is called a multi-objective control system.

We define the manager of the Control System (in the broadest sense of the term) as the subject (individual, group, organ or organization) that, through a series of decisions – based on its particular culture, experience and preferences – can regulate the X_t in order to change the Y_t .

coherent framework of organisations as control systems based on the extant literature. First, the autopoietic approach will be analysed and discussed, then, the holarchic perspective will be introduced although these two approaches adopt a systemic perspective, they will be found to be partial in their analysis of a control system. Therefore, two other approaches will be proposed and applied to the logic of organisations as control systems, namely, the Viable System Model – introduced by Stafford Beer (1978, 1991) – and the Model of the Firm as an Efficient System of Transformation (MEST) – conceptualized by Piero Mella. In fact, the latter two models aim at analysing organisations by adopting a comprehensive systemic approach, since they investigate both the nature of the system's components and the processes performed by each component, as well as the relationships between components, which result in a higher-order systemic behaviour.

Autopoietic View

An organization appears as a social system made up of a multitude of individuals, structurally linked together, that act in a coordinated and cooperative way to form organs specialized in various functions and processes that carry out a network of recursive processes that give rise to an emerging macro process attributable solely to the organization as a whole (Mingers, 2002).

There are several theories and models that allow us to represent the organization as a Control System in which man acts as apparatuses at any level.

Among the various approaches we consider first and foremost the autopoietic view, which considers the organization as an organizationally-closed system that appears in all respects as an autopoietic machine, which is

[...] a machine organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which: (i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them; and (ii) constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network (Maturana, and Varela, 1980: 131)

that tends to endure by continually regenerating the coordinated and cooperative behaviors of its processors (organs) and the network of processes which is a necessary condition for maintaining over time the internal structural coupling among organs and individuals.

Holarchic View

The necessity of coordination and cooperation is more evident if we consider that organs and, in particular, processes are hierarchically arranged and are included in one another; we can then consider organizations as holarchies of holons, even if in different ways (Mella, 2005, 2009a). Individuals are base holons, organs are intermediate holons, and the organization, as a whole, is the top holon that shows emerging properties, according to Arthur Koestler and Ken Wilber's conceptual framework.

Parts and wholes in an absolute sense do not exist in the domain of life.... The organism is to be regarded as a multi-leveled hierarchy of semi-autonomous sub-wholes, branching into sub-wholes of a lower order, and so on. Sub-wholes on any level of the hierarchy are referred to as holons (Koestler, 1967: Appendix I.1).

These sub-wholes – or ‘holons’, as I have proposed to call them – are Janus-faced entities which display both the independent properties of wholes and the dependent properties of parts. (Koestler, 1972: 111-112).

The world is not composed of atoms or symbols or cells or concepts. It is composed of holons (Wilber, 2001: 21).

Due to their Janus-faced nature, holons must necessarily be connected to other holons in a typical vertical tree structure known as a holarchy, which is an arrangement of holons which can be viewed as a multi-layer system (multi-strata) (in the sense of Mesarovic et al., 1970) or a multi-level system with a tree structure (Pichler, 2000; Mella, 2009a).

Viable Systems View

This section will briefly consider Stafford Beer’s model, which is universally recognized as the Viable System Model, or VSM (Beer, 1979, 1981). This model interprets organizations as viable systems that are open, recursive and adaptable and that, thanks to their cognitive and control structure, which is capable of communicating with the economic and non-economic environment, tend to endure for a long time through continual adaptation, even in the presence of disturbances not foreseen at the time of the system’s design and implementation.

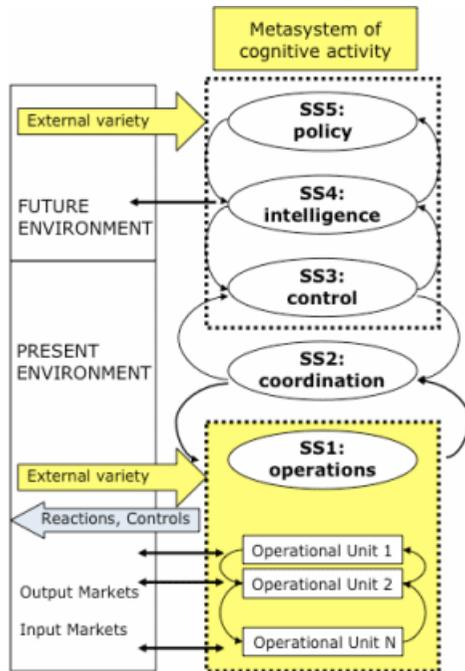


Fig. 2: A Synthesis of the Viable System Model

The VSM outlined in fig. 2 characterizes the vital organization as a structure composed of five interconnected sub-systems (SS):

- SS1: Operations. This represents the operational units, which in turn are viable systems whose purpose is to achieve the operational objectives at the various levels by connecting with the environment, to which they are structurally coupled.
- SS2: Coordination. The operational units of SS1 – which employ common resources and are potentially in competition regarding the objectives – are usually interfering systems that can thus produce, in their local values, an oscillatory dynamics that may cause inefficiencies. For this reason SS2 is charged with coordinating the interconnected operational units according to a logic entirely analogous to the one illustrated in fig. 2.
- SS3: control. Each operational units of SS1 pursue local objectives. They must therefore be directed toward the achievement of the higher-order objectives, which refer to the organizational unit, based on a common programme. The SS3 are charged with this function. The same term used by Beer – the SS of control – clearly reveals that SS3 is a typical Control System based on planning. Since it is capable of activating a range of control levers, SS3 is charged with formulating the utilization strategies of the levers for the various objectives. Nevertheless, SS3 cannot detach itself from subsystems 4 and 5, as it forms together with them a higher-order subsystem that carries out cognitive activities and represents the organization's intelligence.
- SS4: research of information on the environment (intelligence). The survival capacity and vitality conditions of the organization depend on the latter's capacity to continually observe the environment and forecast its "future" state in order to allow SS3 to formulate programmes of action to which it adapts the units and activities of SS1. SS4 represents the viable system element charged with proposing the vital objectives – based on foreseeable future scenarios – and translating these into programmes of action whose implementation it oversees.
- SS5: policy. SS5 is necessary precisely to guarantee that the organization will have a unitary management, together with an entrepreneurial and managerial capacity that can define the policies needed to achieve the vital objectives.

Each of the previously analysed frameworks provides a partial view of organisations as control systems, in that the autopoietic view stressed the control of autopoietic organisations over the internal structure. In fact, the organisational structure maintains its basic relationships, although it changes the components. The holarchic view instead focuses on the control over the micro and macro structure; that is, a control aimed at maintaining over time both the internal structure and the overall structure according to a stated hierarchical structure (holarchy). Beer's approach to organisations is even more focused on the micro level, in that it specifies the nature and the functions characterising each elemental component of any viable organisation. There is, therefore, a need for a more comprehensive framework in order to specify both the basic components forming organisations as control systems as control systems, their functioning, and the relationships between components. After the review of the main systemic frameworks on management literature, a cybernetic model for the organizational structure design will be introduced and discussed.

Organizations as Systems of Efficient Transformation

The preceding models (autopoietic, holonic and viable system models) refer to all organizations independently of the nature of the processes they carry out. But what do production organizations and companies actually do to remain vital and effectively adapt to environmental changes?

To clarify this operative aspect, Piero Mella has introduced a particular framework in which he has identified five functions which are strictly necessary for any productive organization to survive for a long period of time.

Mella’s model interprets firms as systems composed of five sub-systems of interconnected transformation, each of which, operating with maximum efficiency, carries out a vital function similar to what is proposed in the VSM (fig. 3).

While the VSM represents organizations from the point of view of their structural synthesis, the Model of the Firm as an Efficient System of Transformation (MEST) sees them from a functional viewpoint.

Mella starts from the premise that a process/system of transformation is a process/system that carries out some kind (qualitative or quantitative) of transformation of input variables [X_i] into output ones [Y_j] by means of an internal dynamics [S_i], according to an appropriate network of operative processes regulated by specific transformation functions managed by the system’s operative programme (Mella, 2005).

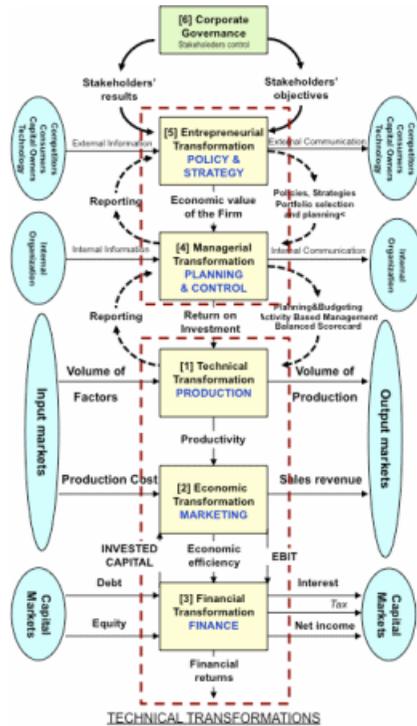


Fig. 3: The MEST in Synthesis (Source: Mella, 2008)

The MEST shows, above all, how each firm must necessarily carry out three efficient “technical” transformations, so defined because they concern the productive, economic and financial functions instrumental in allowing the organization to maintain its functionality in order to satisfy the needs of its stakeholders.

1. **PHYSICAL PRODUCTIVE TRANSFORMATION [TR1-P]**. Inputs, having a given utility, are transformed into products capable of producing a greater utility. The efficiency of the productive transformation is measured by productivity, understood as the capacity of the transformation to generate maximum productive output with the minimum input (consumption) of factors, and by quality, understood as the maximization of the use function of products.

2. **ECONOMIC OR MARKET TRANSFORMATION [TR2-E]**. The firm tries to increase the value of the productive factors, or unit cost, by employing these factors to obtain products that can be traded at remunerative prices, greater than unit cost. Economic efficiency, understood as the capacity to cover the cost flows with revenue flows, is measured by the difference (or ratio) between revenues and the cost of production in a given period.

3. **FINANCIAL TRANSFORMATION [TR3-F]**. To carry out the economic transformation the organization must invest the capital necessary to build the productive structure. This capital – at least during the initial phase of the organization’s existence, when it cannot be obtained by self-financing – must be obtained from investors who, with the expectation of a significant return, accept the risk from the business activity and provide their capital as a relative risk (financing, loans and various forms of debt) or an absolute one (underwritings, equity, shares). From this it follows that the firm must transform the capital raised – relative or absolute risk capital – into remuneration in the form of interest (for loan capital) and profit (for capital contributions). The efficiency of the financial transformation is determined by profitability, which is measured as the ratio between the average return on capital and the average amount of capital, with reference to a given period.

A necessary condition for the firm to carry out the first three “technical” transformations is the undertaking of two “cognitive” transformations: the entrepreneurial (n. 5) and the managerial (n. 4) transformations, whose function is to control the “technical” transformations (we will first consider the entrepreneurial transformation).

4. **MANAGERIAL TRANSFORMATION [TR4-M]**. This is typically a transformation of internal and external information into decisions and planning and control procedures – concerning production, market and financial transformations – which are aimed at achieving the system’s performance objectives. Managerial thinking is typically procedural or conservative, in the spirit of carrying out only successful actions and never repeating the same error twice.

5. **ENTREPRENEURIAL TRANSFORMATION [TR5-E]**. This is typically a transformation of external and internal information into strategic decisions – creative, explorative or innovation-generating (Davenport, 1993), and not only adaptive or reactive decisions – regarding the business portfolio to manage, the technology, markets, prices, and the financial structure. The entrepreneurial transformation, especially in corporations,

is subordinate to a system of corporate governance, which is the expression of the stakeholders that chooses the decision-makers and controls their activities.

As shown in Fig. 3, the policies and strategies elaborated by the TR5-I represent the foundation of the Control System, normally defined as strategic, which acts at the business and general function level, as shown in fig. 4. The TR4-M translates the vital survival objectives, identified by the TR5-I, into operational objectives for whose achievement an operational managerial Control System is developed based on planning and budgeting, as shown in fig. 5.

The TR5-E, in turn, is subject to the Corporate Governance (C.Gov) of the stakeholders.

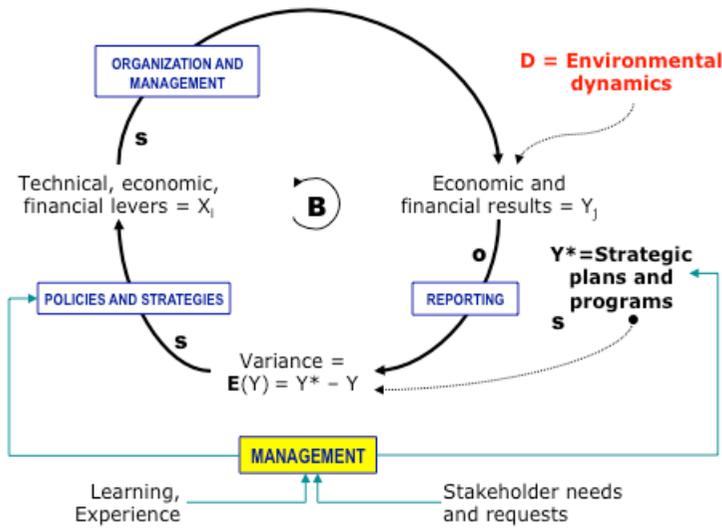


Fig. 4: Strategic Control

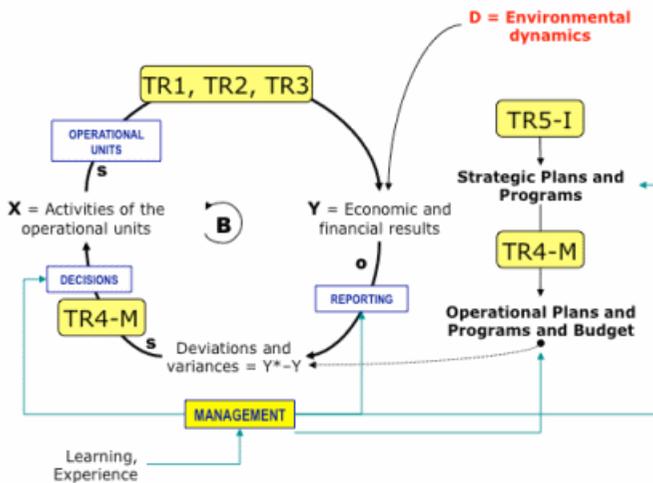


Fig. 5: Operational Managerial Control

The Organization as a Cognitive, Intelligent and Explorative Agent

Long-lasting firm survival depends upon the continual learning process, which allows firms to adapt and self-renew both products and processes, as well as on the overall organizational structure (Volberda and Lewin, 2003).

As an autopoietic system the organization produces itself (Bednarz, 1988; Luhmann, 1995) by developing cognition in order to search for useful energetic and metabolic inputs in the environment and by fleeing from damaging stimuli (Zeleny and Hufford, 1992; Mingers, 1994). In this activity, and by acting as a living system, organizations are capable of forming representations of the external world and of acting (reacting or pro-acting) to regenerate and re-equilibrate the network of vital processes (Von Krogh and Roos, 1995) in order to couple themselves successfully to the environment and survive, even by modifying their own structure in line with the variations permitted by the genetic and operative programme (Uribe, 1981).

A cognitive system is a system whose organization defines a domain of interactions in which it can act with relevance to the maintenance of itself, and the process of cognition is the actual (inductive) acting or behaving in this domain (Maturana and Varela, 1980: 12).

If we define teleonomy as the attitude of the organization to maintain its existence by regenerating its autopoietic processes (Monod, 1970: 25; compare with Maturana-Varela, 1980; 1988), then this unceasing search for the inputs to maintain its existence can be represented by the Control System of fig. 6, which shows how the organizational activity of cognition and learning (de Geus, 1988; Senge, 2006) is necessary for the organization’s teleonomy.

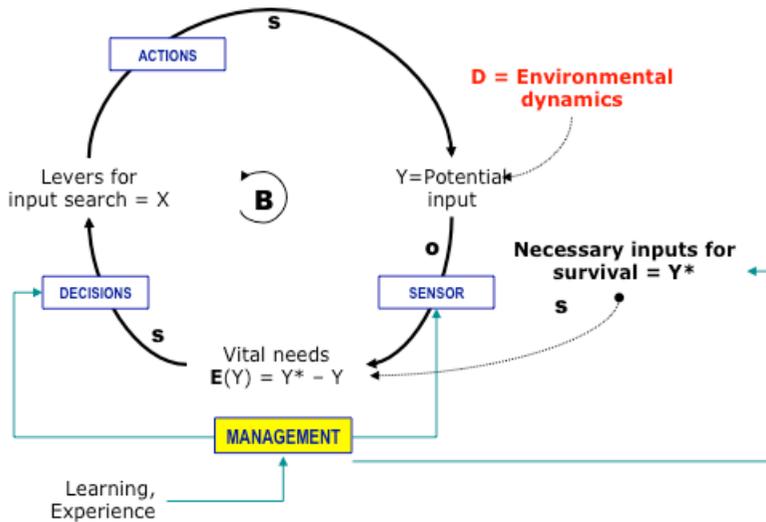


Fig. 6: The Control System that Directs the Teleonomic Behaviour

As a cognitive and viable system, the organization-firm becomes, in all respects, an intelligent and rational economic agent that develops the capacity to control its own structure, its own

processes and its own dynamics in order to achieve increasingly higher levels of efficiency, according to the MEST logic.

It is an economic agent since the organization-firm designs and traces its own trajectory in the productive, economic and financial space in which it operates.

It is an intelligent agent precisely because, as we have observed above (SS4 and SS5 of the VSM, and TR5-1 of the MEST), the organization carries out a cognitive activity that aims at giving a meaning to the environmental stimuli, translating these into information and, through planning, structuring these as knowledge, thereby developing a pro-active behaviour for the long-term reproduction of the economic processes while at the same time anticipating environmental changes.

It is a rational agent in that its cognitive activity must tend toward maximizing the efficiency of the vital transformations by seeking the maximum productive, economic and financial performance.

In its quality as a rational cognitive agent the organization-firm is also an explorative agent which, continually searching for improvement of any kind in its performance, explores its own territorial environment – possibly segmented into areas of interest (continents, states, regions, provinces, etc.) – and “directs” itself toward areas of greater attractiveness; that is, areas where the conditions are favorable to an increase in efficiency: for example, areas that facilitate the creation of new businesses, areas with greater sales volumes or more favorable expectations regarding prices and supply costs, higher social protection, greater environmental incentives, a lower tax burden, and so on (Mella, 2006).

Let us assume that, based on its knowledge (intelligent cognitive agent), the organization-firm can divide the “territory accessible through its own processes” into significant areas, and that, for each of these, it manages to express the value assumed by the performance indicators it desires to maximize; for example, the Economic Value of the Firm (EVF), the Return on Investment (roi), the Return on Equity (roe), etc.

In this way the “accessible territory” is characterized by an attractiveness function that indicates, for each area (and subarea) into which it is divided, the average level for the significant performance indicators, thereby forming an attractiveness landscape that specifies which areas are more attractive and which less so, based on the various performance indicators chosen.

Based on the characteristics of the different areas, it is plausible that the attractiveness landscape will have “valleys” of moderate attractiveness, “peaks” of high attractiveness, or “troughs” of repulsion (no attractiveness) to avoid entirely.

Thus, assuming we have chosen roe and roi, and their components, as performance indicators, it is plausible that an area rich in potential consumers and poor in competitors is highly attractive, since it has potentially high revenues, both from the point of view of quantity and price, and thus a high roi. On the contrary, an area rich in competitors could be scarcely attractive since, precisely due to the competition in terms of price and quality, it would be assumed to have a lower roi; on the other hand, an area with a low tax burden would have, all other things equal, a higher roe than the others and a greater tax burden. An area with a large amount of pedestrian traffic could favor sales for a small retailer, while one with ample parking space could increase the economic and financial performance of a large retail firm.

From the assumption that the organization-firm is a rational agent we derive the following optimal conduct: configure, update and continually explore for future use the attractiveness landscape for those areas accessible with your own productive, economic and financial

transformation processes, trying to avoid the “troughs” and to scale the highest “peaks”: that is, the area where the best performance can be achieved (Demartini, 2009).

Once again the organization-firm, even when it is viewed as an explorative agent, is a Control System, since the objective of achieving a given performance obliges it to continue to explore until it can identify the areas where the objective can be achieved (fig. 7).

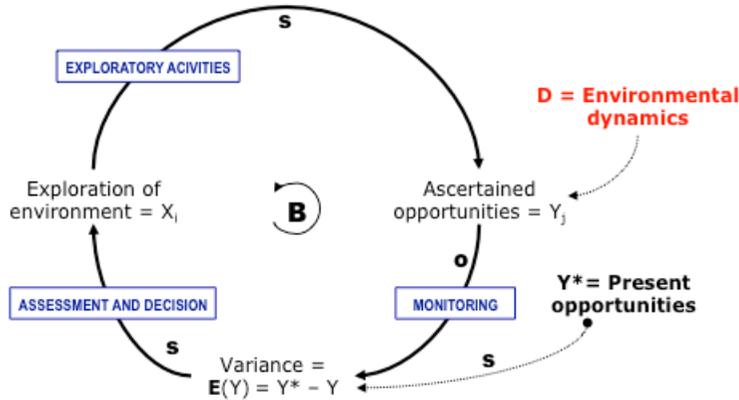


Fig. 7: The Firm as an Explorative System of Achievement

The Implementation of the MEST to both Functional and Organizational Management Control Systems

Fig. 8 proposes a general control system for the operational result.

Fig. 9 and 10 represent a more detailed view of the general models of Control Systems involving the revenue and cost levers shown in fig. 8.

In particular, fig. 9 specifies and analyzes the Control System of production costs developed over several levels.

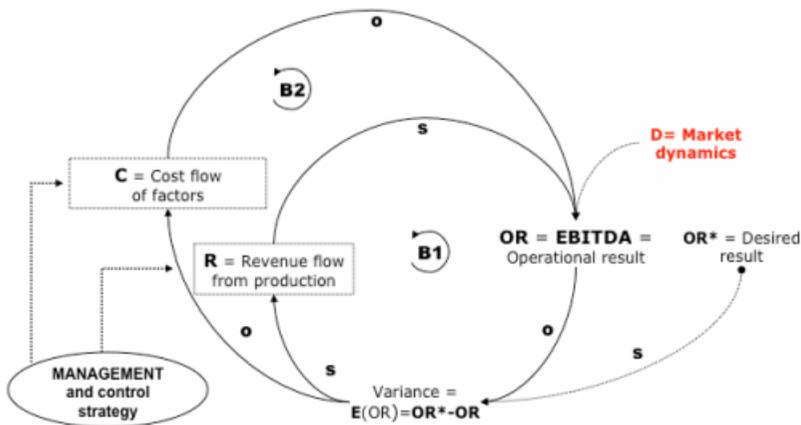


Fig. 8: General Model of a Control System for the Operational Result

The first level, operational control, is based on the two variables that can be influenced in the short term: the purchase price of factors and their unit requirements.

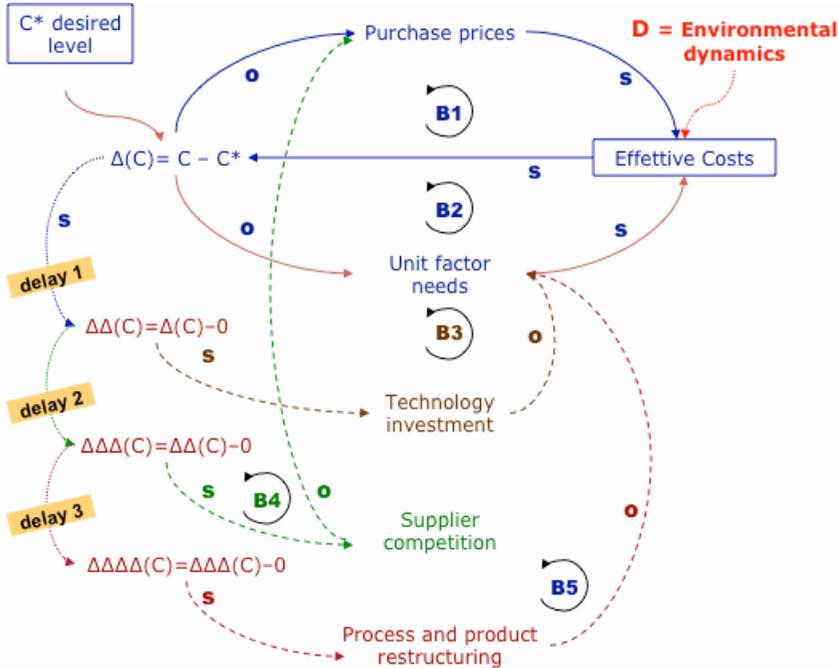


Fig. 9: General Model of a Control System of Costs

In the presence of positive variance (higher-than-desired costs) management tries, on the one hand, to optimize supplies by reducing unit prices as much as possible, and on the other to eliminate waste and redesign the product to reduce unit requirements for materials, manpower, services and other factors.

The other measures available to management (the order in which they appear in the model in fig. 9 is only indicative) are more long-term and structural. Investment in technology and in restructuring the processes are assumed to produce a savings in terms of factors of production; investments to modify the portfolio of suppliers, placing them in competition with one another or trying to obtain better terms from them, should impact the level of supply prices.

Fig. 10 outlines the model of a Control System for revenues, indicated as sales turnover with respect to the desired volumes.

In this case as well, various levels of management intervention are possible: the operational control is carried out on the price and sales volume levers. The other action variables permit a medium-to-long-term structural control; in particular (the order is merely indicative), the strengthening of the sales force and the adoption of monopolistic strategies – or, in any event, strategies capable of strengthening the size advantage – impact the sales volumes; marketing actions, in the form of the strengthening and control of the marketing variables (advertising, promotions, discounts, packaging, etc.) impact the selling price.

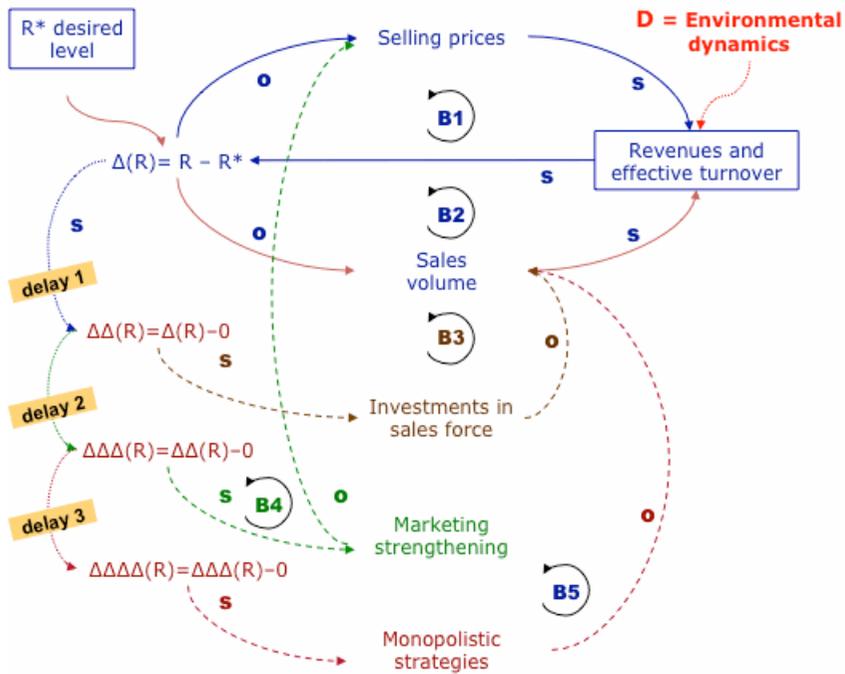


Fig. 10: General Model of a Control System for Revenues

Discussion

In this section an analysis of the frameworks reviewed in sections 2 and 3 will be proposed according to the control system approach.

Firms as Autopoietic Organizations

Reframing Maturana and Varela's approach according to control system theory means that a set of internal Control Systems (fig. 11) must, by acting on information, orders, constraints, motivations, persuasion, rewards/sanctions, etc. (X =control levers), eliminate the errors, $E(Y) = Y^* - Y$, which are the "symptoms of a lack of coordination and cooperation" between the position/objective of an organ A (Y =controllable variable) and the position/objective necessary to maintain the structural coupling with B ($Y^* =$ position/objective of A for purposes of coordinated and cooperative action with respect to B), as a result of the external disturbances (D) that distort the behaviour of organ A.

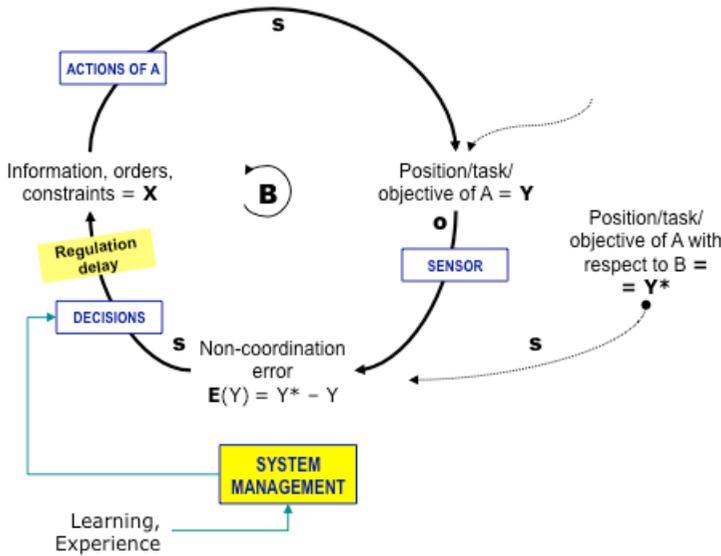


Fig. 11: Control for Co-ordination and Co-operation among Structurally-coupled Individuals or Organs

Firms as Holonic Organizations

According to the holonic perspective, several members of the organization can be included in modules that constitute organs so as to form a modular systemic structure conceived of as an holonic organization capable of achieving a macro objective (Mella, 2009b).

There are at least three interpretations of organizations-firms as holarchies (fig. 12).

1. *Holonic Manufacturing Systems* (HMS) are operational modular holarchies (Schilling, 2000) typically found in the manufacturing or transport industries (Kawamura, 1997; Jacak, 1999). In this case the base holons are machines that form increasingly larger structures (parts of successive structures) that carry out processes that derive from those produced by holons arranged before or below; these holons are necessary for the processes of those positioned after or above.
2. *Bionic Manufacturing Systems* (Okino, 1989; Tharumarajah, Wells, & Nemes, 1996) are top-down holarchies in which the objective of the base holon is to realize a model holon – a modelon – through operational units, or sub-holons, which act as organs in biological systems regulated by strategies, plans, programmes and procedures that serve to synchronize all the production units. The parent modelon is broken down into second-level sub-modelons, and these in turn into third-level sub-sub-modelons, and so on down to the base modelons realized by elementary operational entities.
3. *Fractal Manufacturing Systems* (Savage, 1996; Warnecke, 1993) are bottom-up holarchies formed by autonomous modules whose operational logic is repeated at various vertical levels, like a fractal, reproducing at each level the characteristics of the entire structure. The holonic nature of these structures is found not so much in the processors

(usually men or men-machine production units that self-coordinate) as in the subdivision of the general purpose of the organization in terms of the objectives of the operational units. All the high-level objectives – conceived of as top holons – are pursued through the recursive attainment of lower-level objectives, which are in turn subdivided into sub-objectives, down to the primary operational entities, which are assigned smaller objectives, conceived of as primal holons.

In the three types of holonic organization mentioned above, each holon, irrespective of the interpretation of the component holons (processors, models, or decisions), is a Control System linked to higher-level Control Systems from which, following a top-down relation, it receives objectives and to which, based on a bottom-up relation, it transmits its outputs.

As shown in fig. 12, organizations are, in fact, hierarchies of interconnected Control Systems that permit the organization to carry out emerging processes (products, models and behaviour).

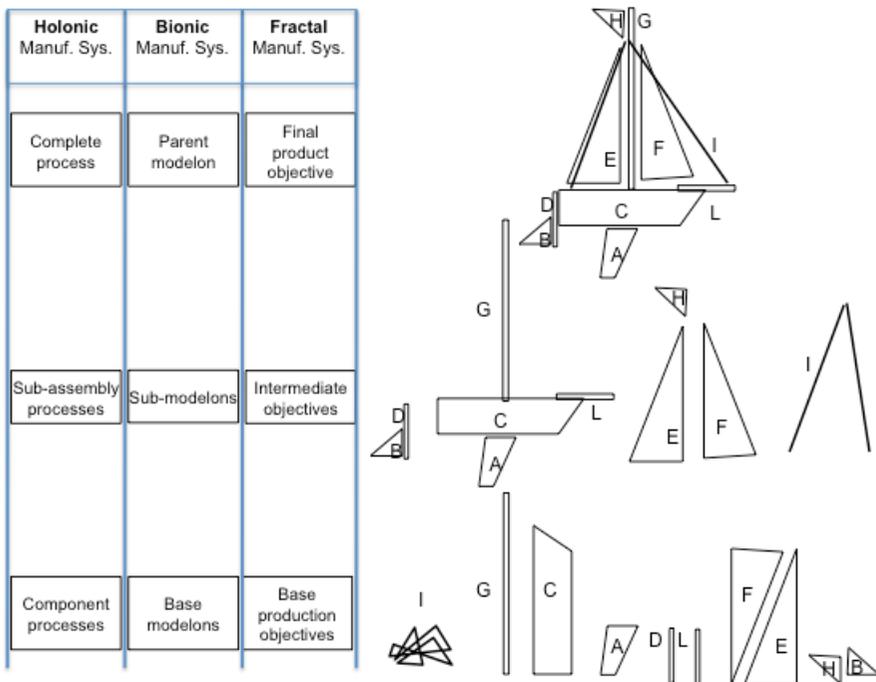


Fig. 12: Three Interpretations of Organizations-firms as Holarchies

Firms as Viable Systems

According to the model outlined in fig. 13 it is possible to observe the VSM as a control system composed of control systems.

Indeed, the operational units that make up the SS1 are unquestionably Control Systems oriented toward objectives and specific and particular constraints, both internal and external.

Furthermore, to complete the VSM, Beer has clearly observed that organizations are multi-objective Control Systems. Thus the control lever strategies used by the lower-order subsys-

tems are not sufficient; instead, a careful assessment and rational ordering of SS4 objectives is vital.

According to Beer, the VSM can also be applied to the organs, groups of organs, or operational units, however defined, that compose the organization, which itself thus appears composed of lower-level viable systems.

Moreover, every organization must always be viewed as part of a larger organization. Beer proposes the following “theorem” which, on the one hand, clarifies the holonic nature of every organization, and on the other highlights the recursiveness of the holarchies.

Recursive System Theorem. In a recursive organizational structure, any viable system contains, and is contained in, a viable system. There is an alternative version of the Theorem as stated in *Brain of the Firm*, which expressed the same point from the opposite angle: ‘if a viable system contains a viable system, then the organizational structure must be recursive’. (Beer, 1979: 118).

In short, with the VSM Beer recognizes that in order to be vital the organization-firm must operate as a unitary Control System, such as the one outlined in fig. 13, where the operational organs are arranged in a holarchy of Control Systems that operate in a similar way to those in fig. 12.

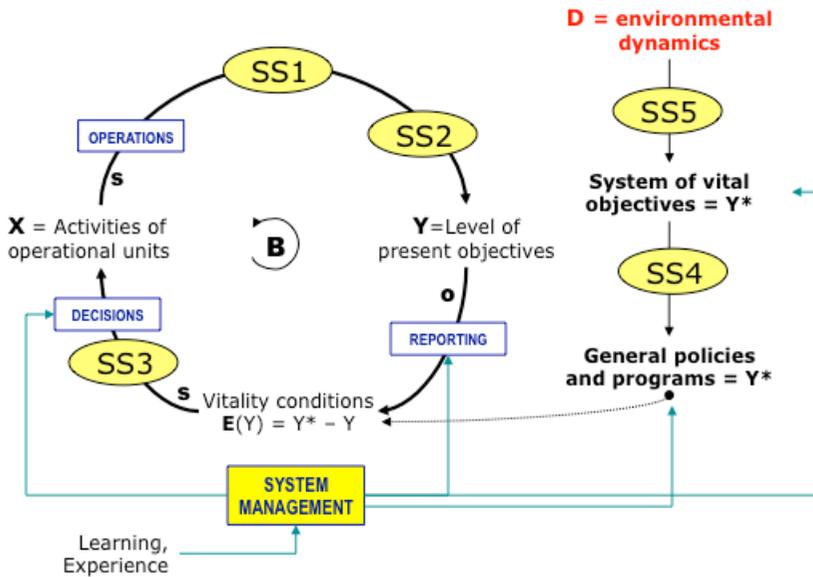


Fig. 13: The VSM as a Control System

Firms as MEST

The MEST contains all the elements of the VSM, as we can immediately see from fig. 14, which is parallel to fig. 13. The operational units of SS1, described by Beer, correspond to the units that produce the “technical transformations” of the MEST. The “cognitive” trans-

formations of the MEST, entrepreneurial and managerial, correspond perfectly to the activities entrusted to the other four subsystems of the VSM.

The MEST differs from the VSM in two respects.

Above all, it explicitly sets out three different control levels: institutional, strategic and operational, each of which pursues objectives of different scope. Secondly, it highlights the possibility of constructing a precise system of performance indicators, represented by the efficiency indicators: productivity, economic efficiency and profitability (in fig. 3 these are only mentioned), all of which can be connected from a value production perspective based on Mella's model (2005).

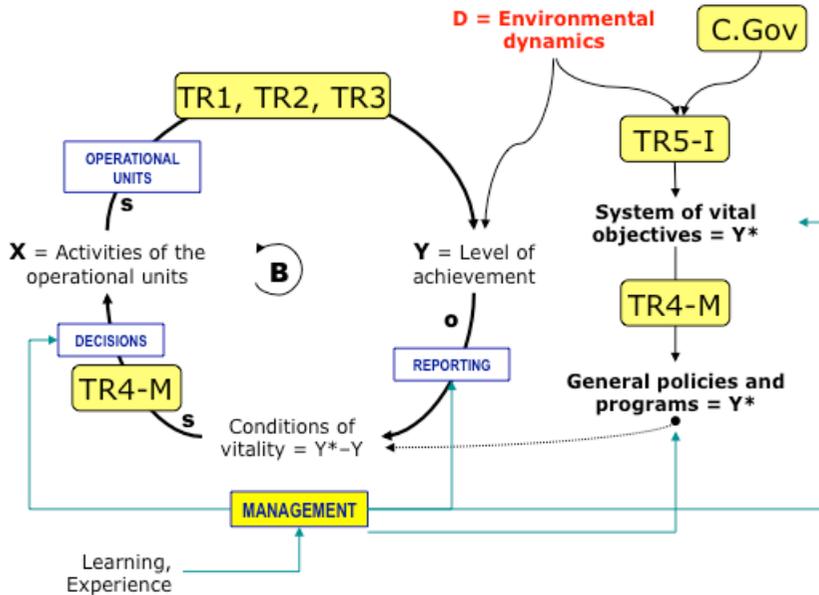


Fig. 14: The MEST as a Unitary Control System

In the MEST as well, the global control system of the organization is, in fact, an holonic system composed of hierarchically-interconnected subsystems of control.

Conclusions and Directions for Future Research

The struggle for survival induces firms to continually learn in order to adapt and self-renew both products and processes as well as their overall organizational structure (Volberda and Lewin, 2003). Control system theory provides a comprehensive approach to the self-renewal, and thus the survival, of the firm.

The objective of this paper has been to introduce and implement a comprehensive cybernetic framework for organizational structure design that enables firms to better cope with and adapt to fast environmental changes.

This study of the logic of control processes that constitute productive organizations and firms and make them vital has led us to the conclusion that organizations are, in all respects, Control Systems, even from various points of view:

1. as autopoietic systems, following Maturana and Varela's conception (section 2.2);
2. as vital systems, following Beer's conception (section 2.3);
3. as systems of efficient transformation (section 3);
4. as Control Systems of performance – multi-objective and multi-levered – that undertake management control at the strategic (section 3.1) and operational (section 3.2) levels.

The main cybernetic views of organisations can be conveniently analysed according to the control systems approach. In fact, autopoietic view develops effective and fast coordination and cooperation between organs, whether a control system is adopted. A control systems VSA enhances the effectiveness in resource sharing, as well as in objective attainment, since each sub-system's objectives is based upon higher order objectives and the reporting mechanism induces lower order sub-units to clearly identify how to effectively and efficiently achieve their goals. The system of efficient transformations develops a twofold objective; an exploratory (strategic) one and a teleonomic (operational) one, by efficiently coping with the environment as well as with the internal structure.

“Looking beyond” toward topics of future research, we propose translating the qualitative models of Systems Thinking used in this study into quantitative models developed along the lines of the System Dynamics approach.

Future research can also be extended to the analysis of the Control Systems that direct the Problem Solving process, which is typical of micro management control.

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