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VIRTUAL ORGANIZATION – CYBERNETIC ECONOMIC SYSTEM. MODELING PARTNER SELECTION PROCESS

Abstract. *Nowadays, at the peak development of information and communication technologies, one of the higher forms of informational society in the business area is the virtual organization. The literature presents various theories on the virtual organizations. They examine aspects of organizational, juridical, managerial, economic nature. This paper will introduce a new paradigm of the virtual organization – the cybernetic economic system. Systemic approach goes beyond the virtual organization characteristics, determined by the simple affiliation to the abstract notion o system – which will be proven below. We will determine how this entity, adopted by the real world, adheres to the laws of the economic cybernetic systems. Also, we will identify the specific elements of informational and managerial nature in the lifecycle of the virtual organization.*
Keywords: *virtual organization, cybernetic system, life cycle, information, management, model, technology.*

JEL Classification: D78, D83, D85

Introduction

Virtual organizations are configurations of semi permanent, interdependent (partial dependent, partial independent) and geographically dispersed structural units which enhance their general performance being receptive to changes in market needs. The literature that examines the general virtualization process and virtual organization of work presents several concepts and definitions for various forms of manifestation of the digital economy and network organization. Virtual organizations are routine formations, representing groups and associations of productive and competitive organizations. The main competitive advantage is the reaction speed to new and complex products that continuously emerge on the market. The simplest way to switch to new products fabrication is selecting available resources from various organizations and synthesizing them into a single electronic business entity – the virtual organization. As long as there are market opportunities, the virtual organization will exists, and when the opportunity disappears, the organization dissolves and the employees will carry on other projects [2].

A virtual organization is first of all a network of independent organizations, from various geographical locations, with a partially commune mission. Within the network, all partners contribute with their own competence and skills and the cooperation is based on semi stabile structures. The products and services delivered are based on innovation and client needs [4].

From the perspective of this paper's theme, the virtual organization is a system where composing entities have more abilities and power than they would have individually. The work frame of the virtual organization is built on four elements:

- *Connectivity*: creation of units or infrastructure through structural changes, removing constraints and going beyond previous barriers;
- *Goal*: the objective that ensure the necessary stimulus to create new organizations and which severs as cohesion force to keep together the components of the virtual organization, at least temporary;
- *Technology*: the helping factor that allows achieving the proposed goals and makes possible the virtual form;
- *Separation*: delimitation of those that are part of the virtual organization from those that are not, in the absence of any visible separation lines.

Laws of cybernetic systems

Beside the general properties derived by the affiliation to the abstract notion of system, cybernetic systems also have specific characteristics, in the form of laws and principles of organization and functioning. Laws of cybernetic systems remain true for the economic organization, in both forms: traditional and virtual. [6].

The law of necessary variation

Ross Ashby [1] has identified and established the law according to which the sum of outputs from a system may be modified by modifying the inputs. Based on this law, there are different types of behavior of dynamic systems, like economic systems. This influence has been explained by analogy with the variance-constraint ratio, where the constraint is a relation between two elements (sub systems) that allow maintaining the variance to a constant level (reduction of variation of one element through the variation of the other). A constraint relation may be weak or strong, its intensity depending on how it affects the reduction of variance. The wider variance in economic and social systems (as opposed to technical systems) comes from more general character of social laws (compared to nature laws). An organic law is not an invariant of the social-economic system (meaning it may be modified by the legislative system), while a nature law is an invariant and constituted as a constraint.

The larger number of degrees of liberty, the higher the variance of the system and the constraints on the system are smaller. According to Ashby law, the direction of modification of a system variance under the influence of inputs is always towards a lower level. This is why the law of necessary variation has a great importance in system control and command. A method to achieve a certain level of complexity on system output is based on the relation between a system behavior variance (VCS) and the variance of its inputs (the perturbations on the system – VPS): $VCS \geq \frac{VPS}{VCA}$, where VCA is the variance of constraints on the system. The higher VCA is, the lower is the system variance.

For the cybernetic system of a virtual organization, the law of variations is obvious. The system complexity derives from the large number of components and the variety of connections between them, which means all elements act to the largest extent of degrees of freedom. This induces a chaotic character to the system, which does not eliminate the complex character of the system (chaos and complexity not being synonyms).

Law of reverse connection

The reverse connection (feed-back) is a fundamental concept of cybernetics, found in the structure of any system and ensuring the functioning of self-regulation mechanisms in order to survive and develop in its environment. Founded by Norbert Wiener, the law establishes that any cybernetic system contains at least one reaction loop (feed-back).

The importance of knowing the feedbacks of a cybernetic system is derived form the systemic approach, because the interactions between elements are more important than the elements themselves. Issuing a command independent from the feedback loop is a certain way to failure because of the system’s elf regulation abilities.

In essence, a feedback loop is a cycle of transformations that, usually, start from an initial value of an input, pass to information which, through a control system, provoke a decision to modify other variables then propagate to the input value. There are two types of feedback loops as elementary structures of any cybernetic system: positive and negative feedback loops. A positive feedback loop always acts towards amplification of a variation on a certain level of the system, with the same direction as the initial variation. We may say that positive feedback loops increase effects. A negative feedback loop generates actions in the opposite direction of the difference between the desired and real value, moving the value towards a desired level, to the root of the system. Negative feedback is a self regulatory mechanism and the consequences of a change of a variable go against the initial variation. In economic systems, the negative feedback (as basic element for behavior identification) is a control and self regulation mechanism which seeks to avoid extremes in the functioning of the system and maintain a relatively efficient equilibrium in the system.

Principle of external complementarities

In many cases, the objects (elements) of a system may be themselves systems or subsystems, the same way that the system of the economic organization is an element of the economic branch system, which himself is a part of the national economic system. This becomes obvious for a virtual organization if we consider its character of network organization, made by participation of several entities. Thus, any cybernetic system constitutes an element (subsystem) of a feedback loop of a higher level cybernetic system. The principle of external complementarities describes clear ways to integrate and interact with the environment, the other systems of the real world (political, economic, social, environmental etc.). This principle eliminates the possibility to analyze the system as a separate element. It must be always approached considering its interaction with other systems, through its inputs and outputs.

General systems complexity prevents classifying them only on the level of a feedback loop of a larger system. The interaction with the environment takes place on the structural flow of several reaction loops. The effect of identifying the principle of external complementarities in functioning of the virtual organization as a cybernetic system reflects in behavior study and synergic approach of the system.

Principle of emergence

First formulated by Herman Haken [3], the principle of emergence (synergy) appears in the systems theory like this: *total effect of interactions and interdependencies is higher than the sum of local effects.* Concrete forms of this principle in economic and social systems include on microeconomic level: agglomeration effect, urbanization effect, finite production effect etc. and, on macroeconomic level the possibilities to achieve global goals linked to quality of life, research, perfection etc.

In economic systems, the synergy appears when interdependent but simultaneous functioning of the elements ensures achieving a higher effect than the sum of effect of the elements if they were working independently. This is a specific effect of the cybernetic systems and manifests itself on organizational and functional levels, as a result of interdependencies between the properties of the system components and the properties of the system as a whole. This characteristic directly influences the behavior of the system and its ability to self regulate in case of variations of environment parameters, all this reflecting in the efficiency of the system.

The synergic effect of a system S, with n subsystems (elements) S^i, may be calculated like this:

$$I(S) = \sum_{i=1}^{n} W^i(S^i) + \Delta(S^1,...,S^n)$$

where I(S) is the total effect of the system, $W^i(S^i)$ is the effect of isolate functioning of the subsystem S^i and $\Delta(S^1...S^n)$ is the synergic effect of interdependent functioning of the n subsystems.

The emergence effect of the system may act positively, leading to an increase of the global effect or negatively, leading to a decrease of the total effect (it may be compared to the effect of a group decision). For each subsystem of a system, we may highlight the components and compute the effect of the subsystem. Due to the system complexity, the principle of synergy may be applied first as the principle of synergic complementarities on the level of component subsystems and then extended as principle of emergence on the level of the global system.

Principle of negative entropy

From the physical-mechanical approach of the economic phenomena, the original meaning of *entropy* comes from the second principle of thermodynamics: *heat always passes from a warmer body to a lower body, never the other way*. Thus the modern interpretation of the entropy law, according to which in every system there is a tendency to transform the order in disorder, chaos.

According to an ordered structure a minimal level of uncertainty (lack of knowledge) and to a chaotic structure the highest level of uncertainty, lead to the term of *informational entropy* as a measure of the uncertainty in a system. There is a direct relation between the level of organizing in a system, the amount of stored information and the level of informational entropy, given by the law of negative entropy: cybernetic systems have a tendency to achieve a higher level of organizing when the amount of stored information increases. In other words, the level of system organizing is proportional to the amount of stored information and reverse proportional to informational entropy of the system:

$$G_{ORG} = \frac{Q_{INF}}{H}$$, where H is the informational entropy of the system.

Information, as basic element of any system, determines the level of organizing of the system and models its behavior, countering the effects of the entropy law and preserving system characteristics: openness, dynamism, complexity and determined chaos.

Virtual organization – cybernetic economic system

Starting from the general definition of a system – according to which it may be any entity in the real life which has an set of components (phenomena, objects, processes, notions, concepts, entities or collectivities) with relation between them and with the outer environment and which act together to achieve well defined purposes – we may easily derive that any virtual organization may be approached as an open, adaptable system, that operates in a business environment based on information and communication technology, through Internet (figure 1).

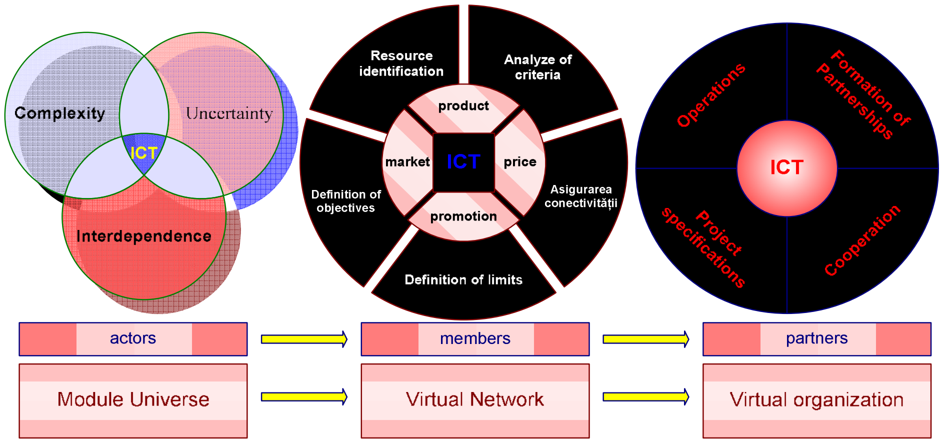

Figure 1. Virtual organization –cybernetic system (from [2])

Viewed as a system, any virtual organization has six interdependent components:

- *Input (X)* – the economical resources like human, financial, materials, machines, terrains, facilities, energy and information, taken from the environment and used inside the system activities (market opportunities).
- *Transformation function (S)* – organizational processes, like research development, production, marketing, sales, that transform the input into output;
- *Output (Y)* – the results of transformation function, which consist of products and services, payments to employees and suppliers, dividends, contributions, taxes and information sent to the outer system (the environment).
- *Feedback (R)* – it is the main element of a cybernetic system, which ensures the self regulation function when the output does not match the goals (Z) set for the system represented by the virtual organization (figure 2).
- *Control* – the management is the control component of an organizational system that targets enterprise functions so that system performance matches the organizational goals (like maximizing the profit).
- *Environment* – any economic organization is an open system, adaptable, that shares input and output elements with other systems in the environment.

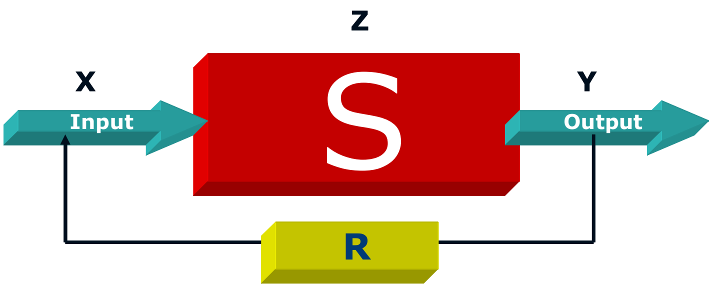

Figure 2. Self regulation (feedback)

Approaching the virtual organization as a cybernetic system is a necessary step to know informational systems in the context of their usage for information processing (also known as data processing). Processing involves applying techniques, procedures and algorithms that will output information to be included in the decision models.

Lifecycle model of the virtual organization

Virtual organization go through four distinct phases during their lifecycle: identification, formation, operation and terminal phase – dissolving (figure 3). Each step presents various provocations and tasks, with tasks, decision processes and managerial activities that initiate and sustain the transformation process. For each sequence of the cycle there are two or more major decision processes. The identification phase involves identifying the opportunities, evaluation and selection of the opportunities and ends when the best market opportunity has been selected. The most important decisions of phase two are linked to identification, evaluation and selection of partners and formation of partnerships. Formation of partnerships involves incorporation of the selected firms into the virtual organization (subsystems of the virtual organization). Once the organization has been formed, the operational phase may begin. Major decisions of this phase involve five functional areas: design, marketing, financial management, production and distribution.

When the market opportunity is exhausted or disappears, the organization ceases to exist. Decision processes in the terminal phase include finishing the operations and distribution of resources. The critical element during the life cycle is the selection of partners, which is why the next part of this paper will present a selection model for the partners in a virtual organization.

Virtual organization management is performed by a virtual agent with the role of a broker within a strategic alliance or a network of organizations. The agent initiates the process of formation of the virtual organization. For example, let's examine the case of an electronic business that requires resources from several service providers. The stages are:

a) Identification of necessary resources. In order to implement the business requirements, a number of G resources must be drawn from market agents: $R = \{R_1, R_2, ..., R_G\}$. Each resource R_i has a set of attributes $a_i = \{a_{i1}, a_{i2}, ..., a_{in_i}\}$ that must be considered in the evaluation algorithm.

b) Partner selection method. There are several types of selection, but here we will adopt a multidimensional bidding mechanism or matrix bidding, where potential partners may present offers for a combination of resources. This kind of bidding has some advantages: a higher level of flexibility in drawing up the offers, economies, a better value (the sum of offer values is higher than the value of a single offer – principle of synergy), lower investments.

c) Feedback. A direct mechanism will be used, which means the potential partners will not be informed about each other's offer.

d) Structure of preferences. No preferences will be used in this algorithm.

e) Structure of the offer. The potential partner will detail the price and quantity for each product/service he offers. In order to conduct the technical analyses, the potential partner will present a comment that includes the date needed in the algorithm. Alternative offers are allowed, but no partial offers for a resource.

f) Evaluation algorithm. The problem is to select a set of market agent so the resource set is optimal with minimal costs. The selection will be conducted based on *the best technical and economical offer* (it will consider both the price and the characteristics of the products/services offered).

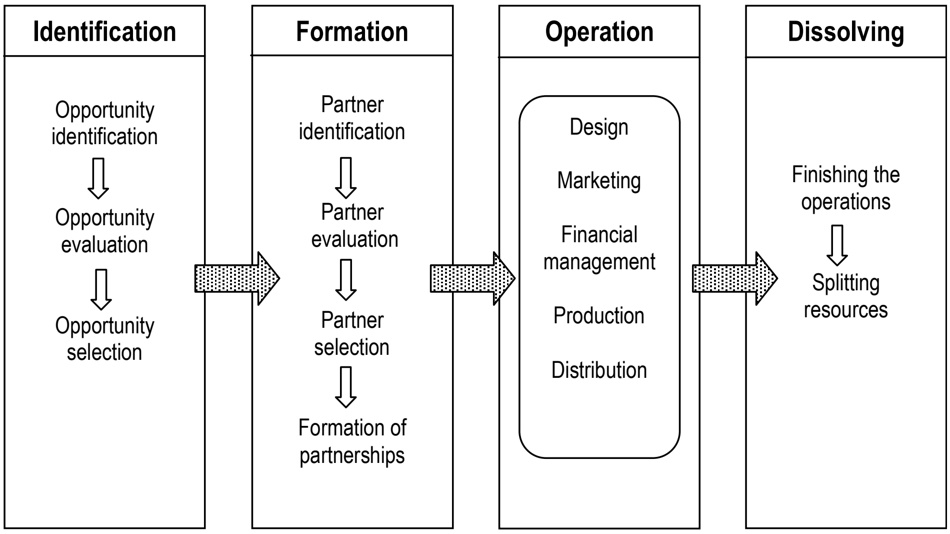

Figure 3. Lifecycle of the virtual organization (from [2])

According to [5], two sets of algorithms may be used to select the best offer: the first one has a polynomial complexity, designed to produce a solution in a finite amount of time (not the best solution); the second one has a non-polynomial complexity but guarantees the best solution. The first algorithm uses the *Greedy* approach, with $O(n^2)$ complexity, where n is the number of potential partners. The second algorithm has a high complexity and requires more time to run. If time is a critical resource, the first algorithm is to b used. If the best solution is required, the second algorithm is the choice.

Let us use the following notations:

- R the set of resources to be purchased, $k \in R$ the index of each resource and q_k the quantity of each resource;
- N the number of potential partners that present offers, $i \in N$ the index of each agent;
- M the maximum number of offers each agent may present, $j \in M$ the index of an offer, O_{ij} the j offer of the i agent;
- $t_{ij}^{\ k} = \begin{cases} 1, \ \textit{if } O_{ij} \textit{ provides the entire amount of resource } k \\ 0, \ \textit{otherwise} \end{cases}$
- p_{ij} the price of offer O_{ij}, computed like this: $p_{ij} = \sum_{k=1}^{G} \Pi_{ij}^{\ k} S_{ij}^{\ k} + c_{ij}$; where Π_{ij}^{k} is the unit price decided by the agent i in offer j for the resource k; S_{ij}^{k} is the offered amount of resource k; c_{ij} is a fixed price of the agent i in offer j;
- $x_{ij} = \begin{cases} 1, \ \textit{if } O_{ij} \textit{ has been allocated} \\ 0, \ \textit{otherwise} \end{cases}$
- $y_i = \begin{cases} 1, \ \textit{if agent } i \textit{ has been allocated} \\ 0, \ \textit{otherwise} \end{cases}$

Evaluation of the offers takes place in two stages: technical and economical. First, the offers are sent for evaluation to an agent specialized in quality characteristics. After evaluation, the quality agent sends his results (as points for each offer) to the broker of the virtual organization. The broker sends the offers and those results to the economic evaluation agent. The economic evaluation agent sends his results back to the broker. On the limit, only one agent may perform all evaluations: the broker of the virtual organization.

a) *The technical evaluation* involves analyzing the quality of each attribute of the resources to be purchased. In order to evaluate the quality characteristics, several methods may be used: automatic monitoring (traffic, network speed); absolute term evaluation service systems (using a point scale); evaluation systems that consider the importance of the attribute and the expectancies of the client, the performance induced by using the service, type of user (adaptation of the buyer satisfaction model).

For each attribute a_i the model computes $E(a_i), P(a_i), Q(a_i) \in [0,1]$, where $E(a_i)$ is the expected quality, $P(a_i)$ is the performance induced by using the service, $Q(a_i)$ represents the points reflecting the importance of the attribute a_i for the user.

$$Q(R_i) = \frac{\sum_{h=1}^{n_i} I(a_{ih}) Q(a_{ih})}{n_i},$$

where $I(a_{ih})$ is the importance of the attribute a_{ih} and $Q(a_{ih})$ is the quality of the attribute a_{ih} $Q(a_{ih}) \cong | P(a_{ih}) - E(a_{ih}) |$

Other criteria that may be used for technical evaluation are: delivery term, infrastructure, organization competencies and components (products, processes, abilities – humans, technologies, practices/procedures), agility, organization image, orientation on client and market, process management, strategic planning and so on.

b) *Economic evaluation.* The winner may be determined this way, without any selection rules:

$$\min \sum_{i=1}^{N} \sum_{j=1}^{M} p_{ij} \cdot x_{ij} \text{ , with the following conditions:}$$

i) there is at least one allocated offer: $\sum_{i=1}^{N} \sum_{j=1}^{M} x_{ij} \geq 1; \textit{where}\, x_{ij} \in \{0,1\}$;

ii) for each agent there is no more than 1 winning offer of the maximum M offers presented: $\sum_{j=1}^{M} x_{ij} \leq 1; (\forall) i \in N \, \textit{and} \, x_{ij} \in \{0,1\}$;

iii) no partial allocations for an offer are allowed $\sum_{j=1}^{M} x_{ij} \geq y_i \; (\forall) i \in N$.

Recent researches (see [5]) present other possible selection restrictions:

i) the number of winning suppliers must be between two limits (lowest F_{min} and highest F_{max}): $F_{\min} \leq \sum_{i=1}^{N} y_i \leq F_{\max}, y_i \in \{0,1\}, (\forall) i \in N$;

ii) The amount that may be allocated to a supplier must be between two limits (lowest $W_{i,min}$ and highest $W_{i,max}$):

$$W_{i,\min} \cdot y_i \leq \sum_{k=1}^{G} \sum_{j=1}^{M} t_{ij}{}^{k} \cdot q^{k} \cdot x_{ij} \leq W_{i,\max} \cdot y_i, (\forall) i \in N, (\forall) j \in M, (\forall) k \in G$$

iii) Budget limitations – the maximum price the organization is willing to pay (B_{max} – max allocated budget): $\sum_{i=1}^{N} \sum_{j=1}^{M} p_{ij} \cdot x_{ij} < B\max$.

The complexity of multidimensional algorithm for virtual organization partners selection (technical and economic evaluation) give the measure of importance for this stage from virtual organization life cycle.

Conclusions

Systemic theory and cybernetic approach allow a holistic perspective (see the principle of synergy) on the problems of the virtual organization, which considers all elements in the matrix of system-environment interactions. The virtual business environment is more important as most of the organization changes are induces by external factors. Adaptability of the organizations is a function that depends on the ability to learn and behave in concordance with environment changes. Complexity and speed of change against the environment lead to high uncertainty in the transactional dependencies of the organization. In order to highlight the efficiency of an organization with the help of systems theory, measures of the organization performance must be related to systemic processes (inputs, transformations, outputs) and the relations between them. This performance depends on structural modification of the business environment, namely its shifting to the virtual world.

REFERENCES

[1] **Ashby W. R. (1956),** ***An Introduction to Cybernetics***, Chapman & Hall, London;
[2] **Ghilic-Micu B., Stoica M. (2004),** ***Virtual Organization***, Economic Publishing House, Bucharest, ISBN 973-709-045-4;
[3] **Haken H. (1993),** ***Advanced Synergetics: Instability Hierarchies of Self-Organizing Systems and Devices***, New York, Springer-Verlag;
[4] **Scarlat E. (2007),** ***From Virtual Enterprises to Digital Business Ecosystems: A Survey on the Modeling and Simulation Methods*****,** Journal of Economic computation and Economic Cybernetics Studies and Research, no. 1-2, http://www.ecocyb.ase.ro/abstract2007.pdf;
[5] **Stoica M., Mircea M. (2006),** *A New Paradigm for Virtual Organization Management*, InfoBUSINESS , Proceedings of International Conference on Business Information Systems, A. I. Cuza University, pp. 267-278, ISBN 978-973-703-207-2/973-703-207-1
[6] **Stoica M. (2005),** ***Economic Informational Systems***. *Concepts and Case Studies*, ASE Publishing House Bucharest, 2005, ISBN 973-594-723-4.