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DECISIONAL SIMULATION WITHIN SOCIO-PRODUCTIVE SYSTEMS WITH ENTROPY

Abstract: *The entire decisional simulation cycle of socio-productive systems obeys the three research levels: analysis, designing and management of the simulation activity. The analysis represents the research process of the system's component with the purpose of highlighting the following issues: the role of the system within the economic enterprise system; their horizontal and vertical interaction within the organisational structure; the status and decision variables – controllable or uncontrollable, which determines the running of the system; the identification of atypical behaviours and factors which influence the good running of the system and which cannot be included in the category of disruptive factors. The management of the simulation activity represents the whole set of planned procedures in view of grouping structures, phenomena and processes analysed and/or designed. By dint of this management a concise and clear formulation results for: the object of the simulation; the purposes pursued; ways of achieving the simulation; preserving, maintaining and updating the essential information achieved as a result of the simulation.*

Key words: *simulation, socio-productive system, the storage of the system, status variable, status entropy.*

JEL Classification: C93, D20

1. Introduction

The complexity, dimension and the scope of the economic problems specific to socio-productive systems require, on the one hand, the structuring and systematisation of their entire simulation activity in view of solving them. On the other hand, they require the adequacy of a relative independence resulted from the very nature of thinking, personality and professional education of analysts. In other words, the stages of creating a simulation procedure are not compulsory, but they cannot be entirely neglected, because there is minimum number of stages and sub-stages for which the optional character is not permitted. One of the major purposes of the analysis of socio-economic systems in general and of socio-productive systems in particular is [17] to evaluate the extent to which the internal actions of the system can modify the status in a positive way and the extent to which this initiative depends on external factors.

N.G.Roengen's (1979) demonstration [9] regarding the way the entropy law acts on any economic system, no matter its size, complexity and role, represents the starting point of theoretical issues with remarkable practical consequences. These consequences will be presented below.

Developing the conceptual elements of the paper [9] this article will investigate possible solutions for a set of fundamental issues such as:

a. Can a social-economic system pass from a given status into any other desired status?
b. Entropy, in its thermodynamics meaning, is a measure of a system's obsolescence. Is there any other type of entropy which leads to the "acceleration" of the thermodynamics entropy in the case of economic-social structures?
c. Is efficiency the cornerstone of the economic science? Is it the ultimate and unique evaluation criterion of the socio-economic systems?
d. Where does the action of efficiency start and end; what comes before and after it?
e. How can be defined the concept of economic system leaving out any ideology?

2. The storage of socio-productive systems

Both in the theory and practice of economics [8], [16] any socio-productive system is characterised by a set of indicators more or less continually changing, by dint of which one can have a clear view of "the status" of the system concerned. Often, these indicators are designed on a wider or narrower time horizon. Thus, they are designed for the short or long term. We mention that very seldom are the effective and structural elements analysed and outlined so that there is at least one perspective if not a real correlation as close as possible to the potential of the system. This potential has to allow it to reach the planned objectives and, as a consequence, to minimise the distance between the future projections and the real statuses that the production system concern will record.

Next, we will assign the values meant to be reached as "**command vectors**" and the real values "**response vectors**". Obviously, any variation of the values of the command vectors from the values of the response vectors in **absolute** and **relative terms** will certainly highlight a certain **"status"** of the system and at least two main aspects:

1. the extent to which anticipations have considered the real status of the production system;

2. the extent to which the system is able to respond to instructions at a certain moment and under certain circumstances (not in “any” given conditions).

Let us consider the general cybernetic scheme of a system (Figure 1) with the mention that, in its known form, it hides an essential aspect.

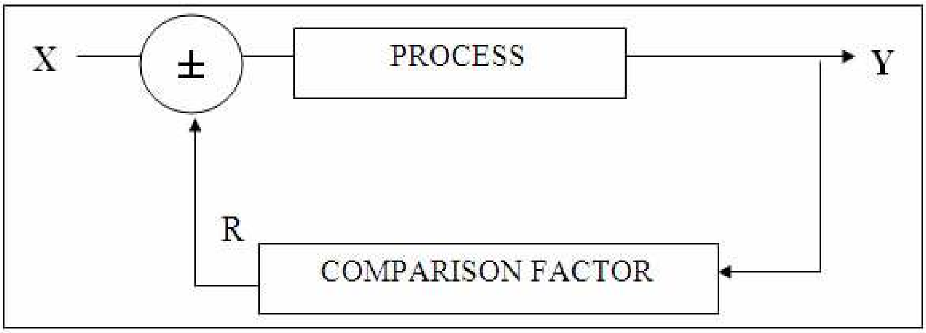

Figure 1: The General Cybernetic Scheme of a System

where:
X – the vector of entry data;
Y – the vector of exit data;
R – the corrections vector.

The relation describing the running of the cybernetic system represented above has the following form:

$$Y(t_n) = F[X(t_n),R(t_n)]. \quad (1)$$

Usually, the size of the exit vector does not correspond to the desired one (commanded or command). This causes the buyer to act as a regulatory element. Implicitly, any additional component (in a functional view) in the system will result in a “delay”. Given this, the above scheme will turn into Figure 2.

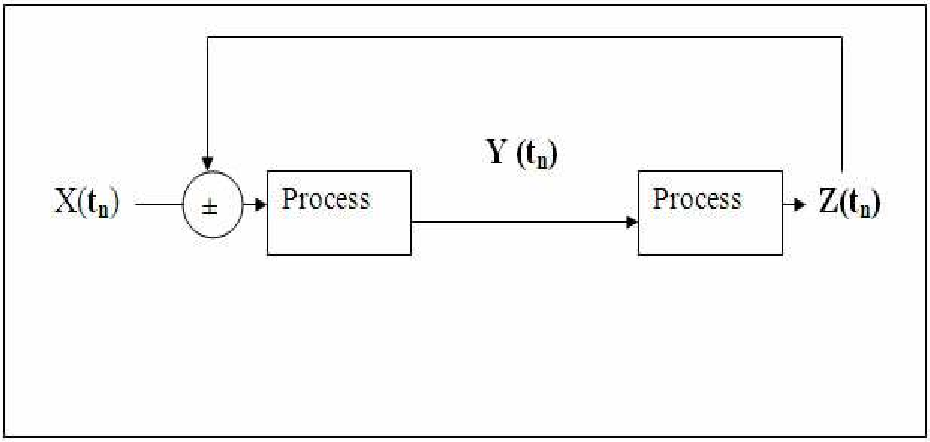

Figure 2: New General Cybernetic Scheme of a System

In this case, the function describing the system in Figure 2 are the following:

$$Y(t_{n+1}) = F[X(t_n),Y(t_n)] \quad (2)$$

$$Z(t_n) = G[X(t_n),Y(t_n)]. \quad (3)$$

If in relation (2) we substitute n -> n-1, we obtain:

$$Y(t_n) = F[X(t_{n-1}),Y(t_{n-1})], \quad (4)$$

Substituting relation (4) into relation (3) we obtain:

$$Z(t_n) = G\{X(t_n),F[X(t_{n-1}),Y(t_{n-1})]\} \quad (5)$$

We notice that according to relation (5) the exit of the system (Z) at a point in time (t_n) depends both on the entries in the system at the given time and on its previous status $F[X(t_{n-1}),Y(t_{n-1})]$.

In other words, the production systems, no matter their type and size, "store" their status, being cybernetic systems characterised by self-regulation ability. Therefore, we can state that production systems are "systems with storage".

Based on the previous demonstrations, we can state the following principle: **any socio-productive system stores its status.** The corollary of this principle is that a **socio-productive system cannot pass from one status to any other.**

3. The status of socio-productive systems

The definition of the status variables are especially the quantification of the status of a production system is, in the economic theory and practice, [1] issues still insufficiently tackled and analysed. This is why will be made several theoretical remarks based on the logics of the economic processes, in a tight correlation with the objective reality and the economic practice. For a start, we will define the **status** of socio-productive systems (this concept is clearly outlined and defined, especially useful in natural sciences – Physics, Chemistry etc.)

In most of the economic analyses of some production processes a wide range of indicators is used (cost, profit, production, productivity etc.). These indicators have are threefold: from the point of view of the person performing the analysis and designing the activity of a production system on a time horizon they can be considered both entry and/or exit variables (in this case, the indicators are accompanied by certain performance indicators) and status variables. According to [3], status variables correspond to the set of values of some significant values, which characterise the evolution and dynamics of a system at certain moments in time (initial, intermediary, final).

As an example, let us consider the indicator "the total cost of production" with the remark that the reasoning, conclusions and generalisation do not change if any other indicator are considered at a later stage.

In the economic practice [6], the cost generally represents a value indicator that expresses the effort of a production system from the standpoint of different resources consumption (entry variables), in order to achieve a certain production (exit variable). As a consequence, this indicator can be considered either an entry variable or an exit variable. Using it, we will characterise the "status" of the production system concerned and will transform this indicator into status variable.

To this purpose, we will consider a time span [0, T] with the discreet time sequences $t_1, t_2, t_3, ... t_n$, so that $[T_K , T_{K+1}]$ C …. Where k=1, …, n.

Let us consider the vector of planned costs C_p and the vector of the incurred costs C_r (the command and the response vectors) corresponding to these time spans.

Let us denote:

$Cp = [C_{1p}, C_{2p}, \ldots C_{np}]$, the command vector of costs

and

$C_r = [C_{1r}, C_{2r}, \ldots C_{nr}]$, the response vector

It is obvious that along the time span considered [0, T] there is a certain variation between the two vectors, which regularly transmits just post-factum information. This means that at a specific moment the incurred cost is different from the planned one or that there is or there is not a certain level of "savings". We set forward to identify, however, a variable that gives us additional information and probably more useful and with a diminished post-factum character. This variable has to convey information that, starting from the results obtained, can justify a possible substantial cost-reduction policy for the next period. If we denote by $\boldsymbol{p_i}$ the probability that at the time moment $\boldsymbol{t_i}$ the incurred cost is equal or within given permitted limits as compared to the planned one, then a measure of the running of the production system under analysis over the time span considered "could be supplied" by the following relation:

$$H = -\sum_{i=0}^{\infty} p_i \times \lg p_i \ , \qquad (6)$$

where H is the entropy of the system in relation with the production costs.

We state that the measure of the system's entropy "could be supplied" by relation (6) on the following ground: it is a sufficient reason that if the probability p_i is nil even for one single time span the relation cannot be applied anymore or the result is useless. In case the permitted limits of the variation between the incurred and the planned cost increase so that every p_i cannot be nil the following question arises: does the result obtained have a satisfactory level of accuracy, quality and confidence?

Let us also consider the case where all p_i =1 and H=0. A nil entropy represents the fact that the production system worked ideally over the time span considered and any type of uncertainty regarding the probability of obtaining equality between the incurred and planned cost is eliminated. Thus, we have decided upon at least two significant causes out of which resulted that a relation of type (6) is does not always hold true.

Resuming the issue of costs as status variables we will perform the following operations:

a. we introduce the ratio

$$I^{i}_{p,i+1} = \frac{C_{i+1,p}}{C_{i,p}} \qquad (7)$$

where $I^{i}_{p,i+1}$ is the coefficient of variation of two subsequent components of the command vector of costs.

b. similarly we constitute the following ratio for the response vector of costs

$$I^{i}_{r,i+1} = \frac{C_{i+1,r}}{C_{i,r}} \qquad (8)$$

where $I^{i}_{r,i+1}$ is the same coefficient, but concerning the response vector of total costs.

Using the two ratios, the vectors below are generated:

$$Ip = \left[I^{1}_{p,2} I^{2}_{p,3} \ldots\ldots I^{1}_{p,i+1} \ldots\ldots I^{n}_{p,n+1} \right],$$

and

$Ir = [I^1_{r,2} I^2_{r,3} ......I^1_{r,i+1} .....I^n_{r,n+1}]$ respectively.

We notice that the two relations highlight the evolution of the command vector *(I_p)* and of the response vector *(I_r)*. In other words, we have transferred the variable of total cost either at the entry or at the exit into the system, transforming in into status variable.

At the end of these considerations, we state the following hypotheses, which will be used next and which state that the quantitative and qualitative measurement of a system can be defined only if the following are known:

a. the direction of evolution (if the system is ordered to move in a certain direction, then the answer has to vary in the same way; otherwise the system is either uncontrollable or its management can be considered inefficient).
b. the relative variation of the response measure from the command one (it shows the extent to which the system is correctly commanded, which means if the command is in accordance with the status).
c. the absolute variation of response measures towards commands.

Under these additional hypotheses we can go on to determine an indicator that can be a measure of the general status of a system.

4. The status entropy of socio-productive systems

Let us consider a random system S that at a certain moment is characterised by an entry vector, a status and an exit one (Figure 3):

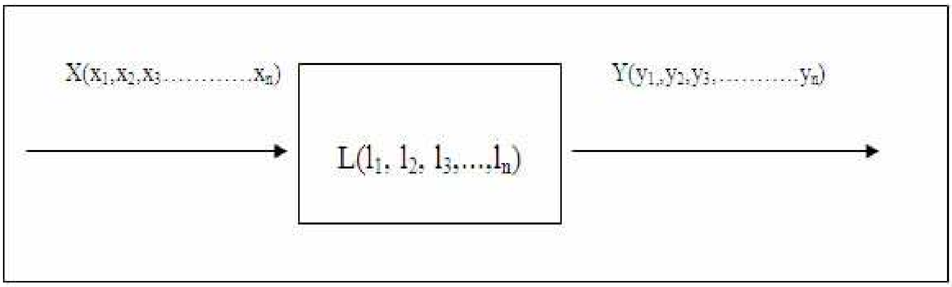

Figure 3: Schema of a Random System

Let us define the **correctly estimated internal status** (L_0) as being the status of system for which we seek **the perfect conformance** between **the command and response measures** (in other words, between the components of the command and response vector). In other words, there is a command variable

$x_0\left(x_1^0, x_2^0, ...x_n^0\right)$ for which the answer $y_0\left(y_1^0, y_2^0, ...y_n^0\right)$ could be obtained only if the status of the system is $l_0\left(l_1^0, l_2^0, ...l_n^0\right)$.

The vector $x_{o,}$ of components $\left(x_1^0, x_2^0, ...x_n^0\right)$ is called command **vector in utter conformance with the status**. Let us also consider the following hypotheses: the application of a command vector in utter conformance with the status cannot conduct to an answer $Y \neq Y_0$.

However, we assume that at a certain moment we apply a command vector $X \neq X_0$ and the answer is $Y \neq Y_0$. In this case the system records an uncontrollable variation resulting to certain extent in an **instantaneous impairment of its internal status**. To this status we associate the concept of **status entropy** (which is different from the entropy from thermodynamics despite the fact that it leads to the variation speed of the former as we can see below)[12].

For a better clarification let us consider two examples (one belonging to the socio-productive field and the other from engineering):

a. Let us consider a production system A for which the technical and material supply is done in strict conformance (qualitatively and quantitatively) with the existing technologies. The other elements of the production process are considered to be objectives at the level concerned. It is obvious that the response of the system (for instance, the production as well as the costs from a qualitative and a quantitative perspective) will be the estimated one. If, however, a certain material is not in conformance with the required quality level or if it has a higher price or if it is not in the sufficient quantity the system will either have a higher specific consumption or it will exceed the costs or it will not reach the planned level of production. In any situation, the production system will be instantaneously "marked" by a deviation or impairment of its internal status, which leads to an increase in its status entropy.
b. Let us now consider a vehicle for which the fuel used is the one recommended in its technical handbook. Thus, let us assume it will respond in a time span of 12s under the acceleration command from 0 to 100km/h (we assume there is no other failure). If we use fuel with a higher or lower octane number than the recommended one then the speed of 100km/h will be reached in a longer or shorter time span or in the same time span the technical state will instantaneously be damaged. In this case, the status entropy will arise.

Next, we will try to build a computation methodology of status entropy, an evaluation, a measure of the internal status of a socio-productive system and not an "indicator" of these statuses. This would not be possible for a simple reason: we do not possess a technology capable of measuring such a status. We are going to show it next that, even if we had one, this would be impossible to achieve due to the infinite number of statuses that could be reached even in a small and relative simple system. This would be even more complicated in a large and complex system like the production system. Let us start by setting the goal of determining the number of statuses that a system with 10 components can go through (serial, parallel or mixt), given that there can only be two relations among the components. Graphically, such a system would look like Figure 4.

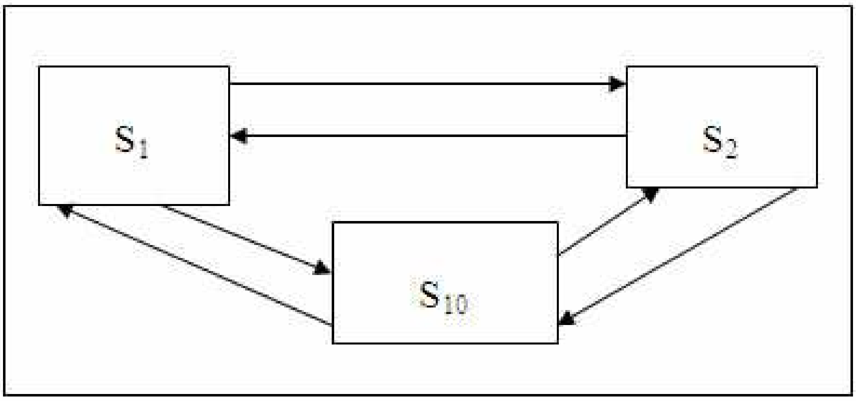

Figure 4: The Production System

Under the conditions of such a system – with small dimensions and a minimum number of connections among the components the number of possible statuses will be:

$$2^{n(n-1)} = 2^{10(10-1)} = 2^{10\bullet 9} = 2^{90} \approx 1.3 \bullet 10^{27}$$

It results that for a small and relatively simple system a number of statuses in other forms cannot be imagined. In this, we will have to reduce this number to an adequate one, which is especially necessary from a practical standpoint. The problem to be solved is the following:

Let us consider a time span [0,T]. We will generate subsequent and discreet time spans (t_k, t_{k+1}), $k = \overline{1,n}$ (the fact that the time spans are considered to be discreet or continuous does not influence the degree of generality of the solution). On each of these time spans we apply the commands x_k to system A and we obtain the response measures y_k. We seek to estimate the status entropy of the system under analysis.

In order to solve this problem we consider the following:

a. we denote the status vector "a" with the components: a_1, a_2, a_3, the vector: $\|a\| = [a_1 a_2 a_3]$ where components a_i, $i = \overline{1.3}$ can only take the binary values 0 and 1.

b. the components of vector "a" have the following meaning:
   - a_1 defines the conformance between the direction of evolution of the command and that of the response;
   - a_2 defines the conformance between the relative variation of the response as compared to the planned one;
   - a_3 defines the conformance between the absolute variation of the response as compared to the planned one.

c. the components of the status vectors can take the following values:

a_1= { 0, if the evolution direction of the response is the same as the one of the command; 1, otherwise;

a_2= { 0, if the variation of the response in relative values is smaller than a maximum permitted value (let us denote it by p); 1, otherwise;

a_3= { 0, if the variation of the response in absolute values is smaller than a maximum permitted value (let us denote it by p); 1, otherwise.

d. we define the vector in utter conformance with the status as being: ||a||=[000].

From the presentation above we can notice that at the level of a production system (regardless the size and nature) a standardized number of maximum 8 statuses has been obtained (Table 1).

Table 1

No.	Status vector	Binary status of the components	Binary complement	Decimal correspondent (c_z)	Modified decimal correspondent (C'_Z)
(0)	(1)	(2)	(3)	(4) .	(5)
1.	a_0	0 0 0	1 1 1	7	8
2.	a_1	0 0 1	1 1 0	6	7
3.	a_2	0 1 0	1 0 1	5	6
4.	a_3	0 1 1	1 0 0	4	5
5.	a_4	1 0 0	0 1 1	3	4
6.	a_5	1 0 1	0 1 0	2	3
7.	a_6	1 1 0	0 0 1	1	2
8.	a_7	1 1 1	0 0 0	0	1

We associate the complement and its decimal correspondent to each binary status, obtaining the data in columns (3) and (4).

We define the modified decimal correspondent (C'_Z) according to the relation:

$$C'_Z = C_Z + 1 \tag{9}$$

Using relation (9) the last column of Table 1 is filled.

We define the probability that at a given time moment (t_k) the system was in the status a_o (the utter conformance of the command status). It is the ratio between the modified correspondent of the vector a_j and the one corresponding to the vector a_0.

$$p_k = \frac{C'_{Z_{jk}}}{C'_{Z_0}} \tag{10}$$

where $j = \overline{1.7}$.

5. Example of simulation of the status of a socio-productive system

Over a quarter, a company sets the following goals:
1. diminishing costs by 2-5%;
2. the costs reduction should be 1.3 - 2 billion lei;
3. increasing the physical production by 1.5% - 2%
4. the additional value of production should be 2.5 - 3 billion lei.

We estimate the status entropy of the system related to the goals set knowing that:
1. the cost reduction was 1.57%;
2. the value of the reduction was 1.2 billion lei;
3. the physical production increased by 1.3%;
4. the additional value of production was 2.8 billion lei.

We will make computations at two levels: the cost level and the physical production level.

From the point of view of costs, we have the following comparisons:
- point 1 was partially achieved: $a_1 = 1$ şi $a_2 = 0$
- point 2 was not achieved: $a_3 = 0$

It results that the costs status vector has the components *[100]*, and its modified decimal correspondent is 4 (corresponding to a_4). The probability to have had a command in conformance with the status is:

$$p_1 = \frac{4}{8} = 0.50$$

Similarly, the same is applied for production and we obtain the vector of components *[101]* (a_1=1, a_2=0, a_3 =1)

And thus:

$$p_2 = \frac{5}{8} = 0.40$$

The status entropy has the form:

$$h = -\frac{\sum_{i=1}^{n} p_i \bullet \lg p_i}{n} \qquad (11)$$

where: n=the number of factors considered.

For our hypothetical situation (n=2) it results:

$$h = \frac{0.5 * \lg 0.5 + 0.4 * \lg 0.4}{2} \approx - \frac{0.5 * (-0.30103) + 0.4 * (-0.39794)}{2} \approx 0.31$$

which shows a low level of the status entropy. Furthermore, we can state that:
- the status of the production system is relatively good (the commands were responded to)
- the decision factor did not reach the quality level intended.

We now own a computation tool useful for indicating with a high probability what can be expected and not from a certain production system from different angles.

We consider that we already know the maximum status entropy within the given system *{*h_{max}*)* and we introduce the ratio

$$R = \frac{h}{h_{\max}} \tag{12}$$

Obviously, $0 \leq R \leq 1$. With the aid of this ratio we introduce the concept of **effectiveness** of the production system, shown by the relation:

$$r = 1 - R. \tag{13}$$

For eliminating any confusion between the terms effectiveness and status entropy we consider that additional explanations are useful.

We can draw the conclusion that the status entropy occurs instantaneously as a consequence of nonconformance situations between commands and the real status of the system at a given moment. These situations of nonconformance first of all display at the level of the structure of the system by transferring them from the coordinates of a normal running to those of "overuse" or "underuse". These variations between relatively or extremely opposed statuses negatively and strongly influence the potential of the system, basically leading to the systematic increase in the variation between the planned and the incurred levels of costs and production.

If the status entropy is a measure of instantaneous impairments resulted from the lack of conformance between command and system status [9], [11], the **effectiveness** is a measure of increasing or decreasing "variations". Thus, this represents a measure of the capacities of the system to be efficient.

It is practically impossible to have utter conformance between the command and the response vector because like any other type of system the socio-productive system needs some kind of flexibility in its running (in case it does not exist, it is implicitly achieved). In other words, it is desirable that to keep a certain "margin" when computing the value of the command vector instead of rendering it "inflexible" unsuccessfully trying to cancel the effects of the status entropy.

The connectivity of the natural systems and that of the social life assume the propagation of the entropy from one system to another (Figure 5).

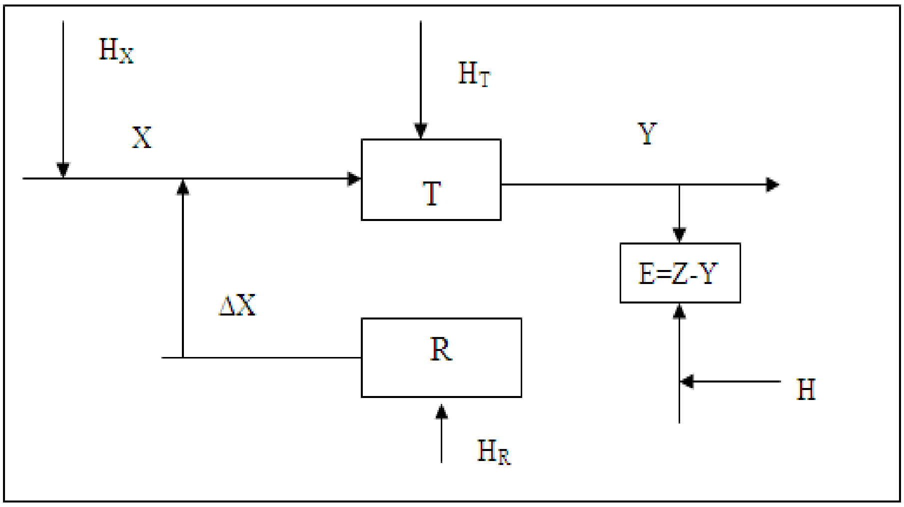

Figure 5: The Model of Entropy Propagation

H_X = the entropy propagated by supplying systems (raw materials, information, financial flows, legislation);
H_T = the internal entropy of effective sub-systems;
H_Z = the entropy of the macro-system (distribution markets, stock exchanges, financial environment etc.);
H_R= the entropy of the management system.

The socio-productive entropy systems with constant objectives in time can be described (Figure 5) by the following matrix relations:

$$\Delta X = \overline{R}[\overline{Z} - Y] \tag{14}$$

where:

$$\overline{R} = R * H_R$$

$$\overline{Z} = Z * H_Z$$

ΔX - The change of the entry values in order to obtain a process leading to the stability of the system.

Next, we obtain:

$$Y = \overline{T}(\overline{X} + \Delta X) = \overline{T}\left(\overline{X} + \overline{R}(\overline{Z} - Y)\right) \tag{15}$$

or:

$$Y = \frac{\overline{X} + \overline{R} * \overline{Z}}{1 + \overline{T} * \overline{R}} * \overline{T} \quad (15')$$

where:

$$\overline{T} = T * H_T$$
$$\overline{X} = X * H_X$$

Substituting Z, T, R and Z we obtain:

$$Y = \frac{T * H_T [X * H_X + R * H_R * Z * H_Z]}{1 + T * H_T * R * H_R} \quad (16)$$

In order to highlight the relation between the four types of entropy we resort to the following simplifications:

- X, T, Z, R will be considered unitary scalars (equal to 1);
- The matrix functions of the entropies are also matrix with one element (of constant value). Setting the condition that Y=1, we will obtain:

$$1 = \frac{H_T * H_X + H_T * H_R * H_Z}{1 + H_T * H_R} \quad (17)$$

or:

$$H_R = \frac{H_X - \frac{1}{H_T}}{1 - H_Z} \quad (17')$$

Setting some values for H_x, H_T and H_z, by simulation we can obtain the behaviour of the system regarding the regulating factors as well as an extremely important managerial principle (Table 2).

Table 2

H_Z	H_X	H_T	$\frac{1}{H_T}$	$H_X - \frac{1}{H_T}$	$1-H_Z$	H_R
0.8	1.0	1.0	1	0	0.2	0
		0.8	1.25	-0.25	0.2	-1.25
		0.6	1.67	-0.67	0.2	-3.35
	0.8	1.0	1	-0.2	0.2	-1
		0.8	1.25	-0.45	0.2	-2.25
		0.6	1.67	-0.87	0.2	-4.35
	0.6	1.0	1	-0.4	0.2	-2.0
		0.8	1.25	-0.65	0.2	-3.25
		0.6	1.67	-1.07	0.2	-5.35
0.7	1.0	1.0	1	0	0.3	0
		0.8	1.25	-0.25	0.3	-0.83
		0.6	1.67	-0.67	0.3	-2.23
	0.8	1.0	1	-0.2	0.3	-0.67
		0.8	1.25	-0.45	0.3	-1.5
		0.6	1.67	-0.87	0.3	-2.9
	0.6	1.0	1	-0.4	0.3	-1.33
		0.8	1.25	-0.65	0.3	-2.16
		0.6	1.67	-1.07	0.3	-3.57
0.6	1.0	1.0	1	0	0.4	0
		0.8	1.25	-0.25	0.4	-0.625
		0.6	1.67	-0.67	0.4	-1.675
	0.8	1.0	1	-0.2	0.4	-0.5
		0.8	1.25	-0.45	0.4	-1.125
		0.6	1.67	-0.87	0.4	-2.175
	0.6	1.0	1	-0.4	0.4	-1
		0.8	1.25	-0.65	0.4	-1.625
		0.6	1.67	-1.07	0.4	-2.675

By briefly analyzing the data in the table above it results that the influences on the regulating capacity decrease in the following order:

- objectives
- production capacities
- entries.

6. Conclusions

In the study [18] regarding the mathematical theory of information it is proven for the first time that it is possible to define a measure of information with major impact on the communication theory and the theory of cybernetic systems regulations in general and of production systems in particular. The importance of this study is significant from at least two points of view:

a. many important problems regarding socio-productive systems can be successfully tackled in the light of regulation theory;
b. theoretical approach is most often useful even though it does not have immediate and discreet applicability in the management practice, because it highlights main issues concerning the behavior of production systems. If they are neglected or ignored negative comparable consequences may arise within an unfavorable economic environment.

These two aspects have been highlighted over the paper, which establishes new approaching directions of the relation between an efficient production system and an economic production system. The results of the above-mentioned reasoning allow us to define the **principle** according to which in order to maximize the results of the management sub-system of the production activity one has to pursue **objectives stability** in the first place , followed by **the stability of production capacities** and finally **the stability resources availability.**

Within such an approach, we consider that the **effectiveness of a production system is bestowed by the extent to which the functions of the system ensure the achievement of some performance indicators, as well as its ability, safety and credibility in order to globally and utterly answer to the requirements of an efficient command vector.**

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