ON THE RELIABILITY OF INFORMATION AS A CYBERNETIC TECHNICO-ECONOMIC PROBLEM

Nikolay Ivanov Petrov

Abstract— Cybernetics looks at machinery, living (dead) organisms and the world society with its technico-economic problems as an organized integral formation (system). In the process of evolution this system, in its natural historical course or artificially, has reached to a certain level of organization, according to the relevant qualitatively determined structure or degree of complexity.

The main laws and principles of cybernetics are related to the reliability of the functioning systems, determined for a relevant relative time interval. The information about them defines the objects and their elements, not as a general management system but as a system having a certain combination of general and specific structural and functional properties.

The purpose of the present article is to determine the quantity of reliable information about the condition of the cybernetic systems, their objects and elements (including human beings with their history, culture and morality).

Index Terms— Reliability of information, Cybernetics, Systems, Objects, Elements

---

1 Introduction

The cybernetic system (CS) is a complex dynamic system in the basis of functioning, the foundation of the information interaction between the functional elements (FE) of its subsystems (objects) and the entire system with the external environment. In this interaction the key role belongs to the reliability of information used for its management (N. Wiener, 1958) [0].

A complex dynamic system should mean a system of objects developing in time and space (a set of FE, together with their interrelations), having different properties from its constituent elements (Berg A., 1964) [1].

The complex dynamic system may also be studied from the point of view of the management processes and operations. On the other part, the following definition of a management system should be taken into consideration: ,,Processes and operations causing transformation of the system from one condition into another and securing its reliability and sustainability of functioning" (Berg A., N. Bernstein, 1962) [2]. For the purpose of introduction of a definition for TES, it is important to find out what is an external environment, why it is incorrect to differentiate and classify the systems according to the type of relationship thereto. Moreover, the following principle should be introduced: „The concept of environment includes objects, phenomena (static and dynamic), not included in the relevant material system but not all of them – only those which have a significant influence thereupon... The concept of environment also includes all objects and phenomena which experience well expressed direct influence of the system in question" (Muller Karl. The New Science of Cybernetics. The Evolution of Living Research Designs. Vol. 1. Methodology. ,,Remaprint", Vienna, 2008) [3].

• *Nikolay Iv. Petrov, Prof., D.Sc.,D.Ec.Sc.; 1784 Sofia, Poligona Str., № 8, Fl. 70. Phone: +359-2-974-46-91; E-mail: nikipetrov_1953@abv.bg*
• *On 7.04.2015, he was elected Academician of Bulgarian Aca-demy of Science and Arts in the direction of information systems.In 2007 he awarded Professor by specialty, Atomized Systems for Treatment of Information and Control.*

It is worth noting that not only the impact of the external environment on the system should be examined, but also the impact on the system on the environment. This requirement is a necessary condition for the functioning and development of the cybernetic systems. It is necessary to take into consideration that the organizational level of the artificial cybernetic systems (robots, synthesizers, intelligent buildings, etc.) may eventually reach the organizational level of the systems from the living nature [10, 11].

Under these circumstances there will come a time when the robots will have the right to search for an alternative form of the so called „civil rights".

2. Lemma on the Functioning of the Cybernetic System

Cybernetics studies those systems which have reached a certain, sufficiently high level of organization and have the relevant structure, enabling their determination as information systems managed under a specific algorithm (program).

Generally not all systems in nature are considered cybernetic. In other words, any cybernetic system should satisfy the following requirements (conditions):

- to have a certain level of organization and structure, securing its reliability and sustainability;
- to be able to assume, store, process and utilize information, i.e. to be an information system;
- to have a program (management algorithm) using the principle of feedback [4, 7].

The objects from the inorganic nature in their large part are systems which have not reached the organizational level of the information systems. Therefore in most cases they are ready to serve as a channel for transmission of information to more organized systems, as the information bearer is an energetic process.

In other words, the objects from the inorganic nature are a system, which according to the definition of William Ashby, in most cases is „closed for energy but open for information". The science of cybernetics studies the principles of functioning and the reliability of the systems which are „open for energy but closed for information" [5].

The above reflections on the cybernetic systems operating in different conditions, lead to the following Lemma:

The cybernetic systems (CS) and the biological systems (the living nature) are not identical. The process of constant renewal of the chemical compounds of the biological systems influences all manifestations of vital activity. Without rejecting the qualitative difference between the living and non-living nature, it should not be considered that there is an eternal border, i.e. there are also many common things between the two types of nature.

This Lema leads to the conclusion that the methods of cybernetics generally may not spread on the phenomena from the inorganic nature. Therefore such phenomena, being an element of the inorganic nature, may not be reviewed as cybernetic systems. In a more general plan, however, it is possible to examine information processes in inorganic nature.

It is known that information is directly related to enthropy (the measure of uncertainty). Along with this, there is a deep dialectical connection between uncertainty and information, which is subject to permanent studies.

3. Information and uncertainty of TES

Information is simply opposite to uncertainty, i.e. it is uncertainty with the relevant level of reliability [7].

Such understanding of information includes the order and disorder as private cases of uncertainty and certainty. This is the core of the interesting dialectical approach to the meaning and essence of the reliability of information in a certain TES. It exists thanks to the permanent replacement of uncertainty with certainty in the relationships and interactions of the elements within the studied system. To this end information and its reliability play an essential role for the quality of management of the cybernetic systems which have a different existence and accompany the economic and social processes, for example.

Let us mark the function of uncertainty of the relevant TES with $f_{UN}(y)$where y is the number of its exits. Then in a system with one possible exit y=1 the uncertainty would not exist, i.e. the following equation would be fulfilled

$$f_{UN}(1) = 0 \tag{1}$$

Then (1) and the renown article of Shannon C. A, Mathematical Theory of Communication. The Bell System Technical Journal, Vol. 27, pp. 379-423, 1948 [4], lead to the three properties of the function of uncertainty:

$$f_{UN}(1) = 0;$$
$$f_{UN}(m) \le f_{UN}(n);\ m \le n;$$
$$f_{UN}(mn) = f_{UN}(m) + f_{UN}(n) \tag{2}$$

where: m and n are the number of exits of the studied system in the different time mo-ments (intervals).

The only function satisfying the conditions (2) is the logarithmic function. This means that uncertainty is not any function of the number of exits of the system but is proportionate to the logarithmic function. If the uncertainty function $f_{UN}(y) = N$ is designated and the number of exits of the studied TES is n, the following equation is obtained

$$N = k.logn \tag{3}$$

where: k is determined from the selected base of the logarithm.

After occurrence of the completed event in the studied system, the uncertainty N turns into information about the reliability of the event and the probability for reliability work of the event is $P_{RW}(\Delta t) = 1$ in a studied time interval Δt [8, 9, 10]. The function of the quantity of information is marked with I, so

$$I = N = k.logn \tag{4}$$

Transformation of (4) is performed in the following manner:

$$I = k.logn = -klog\frac{1}{n} = -k\sum_{i=1}^{n}\frac{1}{i}log\frac{1}{n} \tag{5}$$

From (5) the following equation comes:

$$I = -k\sum_{i=1}^{n}\frac{1}{i}log\frac{1}{n} \tag{6}$$

Equation (6) is completed at random base of the logarithm and the value of coefficient k depends on the selected base.

Let us have a closer look at (6). The number of possible cases or the number of possible exits of the system is marked with n. Where all cases have equal probability, then the probability of each of them is marked with $1/n$. For example, when throwing dice, the probability to get 6, 5 or 1 is always $1/6$, and when throwing a coin – always $1/2$. Obviously, in practice the systems with equally probable exits are not so frequent. This requires a summary of the obtained formula (6).

If a TE system has n exits and each exit has a probability of occurrence (realization) p_i, provided that the condition $0 \le p_i \le 1$ is met. In such case the following would be true:

$$\sum_{i=1}^{n} p_i = 1 \tag{7}$$

because in at least one of the possible cases p_i should be realized.

Following (7), (6) should be transformed as follows:

$$I = -k \sum_{i=1}^{n} p_i log p_i \qquad (8)$$

Now the outstanding question is related to the measurement of the information in the TES through formula (8), i.e. the unit measure. It is natural to accept the least quantity of information as a unit measure. Having in mind the properties of the function of uncertainty $f_{UN}(y)$ of a management system, presented by (2), it would mean that the least quantity of information other than zero would be obtained when $n = 2$. This is typical for a mana-gement system with two exits, i.e. information system with two levels – 0 and 1; TES with two conditions - „working – faulty"; diagnostic transportation system with two con-ditions „there is/there isn't", the position of the coin „heads or tails", etc.

As noted herein above, the two symbols are sufficient for the transmission of any discrete message. Therefore the quantity of information for transmission of two symbols would be:

$$I_2 = -k \sum_{i=1}^{n} 1/i.log_2 0,5 = 1 \qquad (9)$$

As k is a random coefficient, then especially for CS it is assumed to be equal to one, which leads to [9]:

$$I_2 = -\sum_{i=1}^{2} 1/i.log_2 0,5 = 1$$

and from there the base of the logarithm in equation (8) is determined. It is easy to see that the base of the logarithm would be equal to two.

Therefore the quantity of information I_2 would be a unit measure. It is called bit. Any management system (information, technico-economic, chemical, biological, etc.), with two possible conditions at the exit („yes-no") contains one bit of information.

Formula (8) is finally written as:

$$I = -k \sum_{i=1}^{n} p_i log_2 p_i ; \sum_{i=1}^{n} p_i = 1. \qquad (10)$$

Formula (10) is called Shannon's formula for the quantity of information passing through a random technical and economic management system [7]. This formula has been applied more and more extensively in the scientific, technical, social and educational systems and networks, management and culture of the information societies.

The contemporary theory of information has obtained such development that there are possibilities for automatic computation of the different types of information exchanged between the systems. However, in the economic and social sphere the use of the theory of information is almost never applied. Usually only formula (10) is used for the quantity of information in some flow of documents, computed on the basis of the symbols used. A scientific revolution in this field is coming.

It is worth noting that a long time before Claude Shannon discovered formula (10) for the quantity of information, Norbert Wiener and the English statistician Fisher have reached to the common idea of the use of information in the economic and social systems. It was discovered by Boltzmann and applied for measurement of disorder (chaos) of physical and chemical particles (i.e. for measurement of particles entropy). Therefore it is correct to call formula (10) **formula of Boltzmann-Shannon**.

From equation (10) leads to the important conclusion:

The more exits there are in a studied system (TES, more specifically), which means higher level of uncertainty, the less reliability it has within the studied space of con-ditions.

The above statement gives an opportunity to build the fol-lowing reliability-information structural scheme of a technico-economic system (TES) and its cybernetic management fig.1:

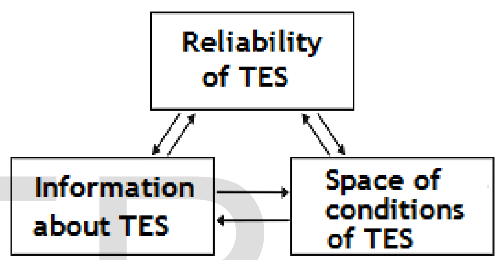

Fig. 1 Reliability-information structural scheme of TES

4. Determinaton of the quantity of reliable information

The scheme of the reliability and information structure of TES (fig. 1) leads to the formula for quantity of information (flowing in two directions and in cycles through the system), its reliability and the reliability of functioning of TES, i.e. the formula for **quantity of reliable information** $I_{RI}(\Delta t)$ within the observation interval Δt:

$$I_{RI}(\Delta t) = -\sum_{i=1}^{n} p_i log_2 p_i .P_{RW}(\Delta t) \qquad (11)$$

In (11) the function for **probability for reliability work** $P_{RW}(\Delta t)$ of the system within the observation interval $\Delta t = t_2 - t_1$ is determined by the main Reliability law for TES at stationary, ordinary flow of refusals and lack of consequences, in accordance with the equation:

$$P_{RW}(t_1, t_2) = e^{-\int_{t_1}^{t_2} \omega(t)dt} = exp\left[-\int_{t_1}^{t_2} \omega(t)dt\right] \qquad (12)$$

Equation (11) and (12) lead to the final formula for the **quantity of reliable information** $I_{RI}(\Delta t)$ passing through one TES for a relative time interval Δt:

$$I_{RI}(\Delta t) = -\sum_{i=1}^{n} p_i log_2 p_i .exp\left[-\int_{t_1}^{t_2} \omega(t) dt \right] \qquad (13)$$

The measurement unit of the new reliability specification for the quantity of infor-mation is Bit-Fita.

We must remember that the unit for measurement of the intensity of a flow of failures (refusals) is called Fit and 1 Fit = 1 fail/h, i.e. the occurrence of one refusal (violation) in TES for a time interval of one hour. The measurement of the intensity of the flow of refusals, damages, violations, cracks, errors, falsifications, etc. is especially topical for the security of the contemporary information society [12].

4. Conclusions

As a result of this study performed by the author of this paper, the following results have been obtained:

1. A formula for the quantity of reliable information has been determined for a relevant relative time interval. This formula is a basic moment of the cybernetic management of the society and its technical and economic systems.
2. Having in mind the principle of William Ashby that the „objects of inorganic nature are closed for energy but open for information", this formula can be used for a quantitative connection between the inorganicand organic world of nature.
3. The reliability of information in the contemporary technico-economic world has a fundamental nature (see the additionally obtained results in [11]). It defines a new technico-economic strategy for cybernetic management of the world on the background of the occurred challenges and contradictions at the beginning of 21-st century.

References

[0] Wiener, N. Cybernetics and Society. Nauka, Moskow, 1958.
[1] Berg, A. Cybernetics and Reliability. Nauka, Moskow, 1964.
[2] Berg, A., N. Bernstain, and oder. Cybernetics. Moskow, 1962.
[3] Muller, K. The New Science of Cybernetics. The Evolution of Living Research Designs. Vol. 1. Methodology. „Remaprint", Vienna, 2008.
[4] Shannon, C. A. Mathematical Theory of Communication. The Bell System Technical Journal, Vol. 27, pp. 379-423, 1948.
[5] Petrov, N.I. Relativity Index of the Reliability of Space Systems. International Journal of Computing, v. 10, Is. 2, 2011, p. 179-182.
[6] Petrov, N. Reliability's Investigation of Risk Technical Systems. Monograph. Trakia University – Turkey – Bulgaria - Greece, First additionally publication, 2006.
[7] Petrov, N. Probability, Independence, Information Society. Monograph. Poland, 2012, Publ. „Wydawnictwo Astra", Lodz, First publiccation, ISBN 978-83-63158-20-0, p.p. 1-168.
[8] Petrov, N., N. Atanasov. A Theorem for the Price of Reliability. International Journal of Innovative Science, Engineering & Technology, ISSN 2348–7968, V. 1, Is. 8, 2014, pp.117-122.
[9] Nikolov, Iv. Cybernetics and Economics. „Scients and Arts", Sofia, 1971, p. 137.
[10] Petrov, N. Izsledvane na operatsiite по osiguryavane na nadejdnostta na riskovi techniko-ikonomicheski sistemi. AI „Prof. Marin Drinov", BAS, Sofia, 2014.
[11] Petrov, N. Reliability as a basical tecno-economic problem by cybernising of society. Thesis for the award of degree „ Doctor of Economic Sciences". Varna Free University „Chernorizets Hrabar", Varna, May, 2015.
[12] Petrov, N., V. Dimitrov. Forecasting the Technical Resource of the Mechanical and Civil Bulding Structure. International Journal of Civil Engineering & Technology (IJCIET), v.7, Is.3, 2016, pp. 173-181, ISSN Print: 0976-6308 and ISSN Online: 0976-6316, I.F.(2016): 9,7820.