Evaluation of Information Entropy in Organizational System

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ABSTRACT
Entropy, as a thermodynamic concept, indicates the degree of system disorganization. The concept of entropy is associated with a measure of disorder and uncertainty in a physical system that leads to progressive loss of the relationships that integrate a system. The study of entropy becomes relevant for organization systems, which are described as interconnected elements, having a defined goal, and interacting with a dynamic environment. These systems are essentially based on the acquisition and application of information to ensure their self-determination and future development. In such a context, the approach of entropy is related to the Information Theory, referring to a measure of the amount of information that exists in an organizational system.
This paper discusses the concept of information entropy and proposes a manner to evaluate its level under the influence of certain events that reveals particular organizational aspects. A case study for testing the relationship between information and entropy in the case of a company has been elaborated. The findings reveal that the increasing of order within a company system, through highly structured states leads to low level of information entropy.

KEYWORDS: *entropy, event, information entropy, organizational system, probability.*

JEL CLASSIFICATION: *M21, D8.*

1. INTRODUCTION

Information and communication processes reported in internal and external environment of companies are characterized by a wide variety of information, in terms of content, forms of expression, quality and quantity. This diversity of information correlated - not least – with their specific features leads to real problems, both in the information system and causal relations existing in the entire dynamic system of organization. This is the general framework in which the information entropy will be analyzed.

The concept of entropy, originated in the study of thermodynamic systems, has emerged in social sciences by revealing the relationship between two concepts: information and entropy. A comprehensive approach was proposed by pioneers such as Wiener (1948) and Shannon (1949). According to information theory of Shannon, the entropy is a generic measure which can be applied to any systems for which information exists. Information theory is a research area that provides the characteristics of dynamic systems and their behaviors, including nonlinear behaviors and relationships. Inspired from the work of Shannon, Haken (2006) says that information is quantifiable as the amount of order or organization provided by a message. The entropy reflects the measure of this order. Since organization is conceived as a system, it

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is possible to apply the concepts of entropy and information to study how their relationship affects the equilibrium state of the company system.

2. BACKGROUND AND LITERATURE REVIEW

The term entropy was introduced by Rudolf Clausius in 1865, starting from the formulation of the second law of thermodynamics. According to this law, in a closed system (i.e., without outside intervention), heat always flows from a warm body to a body with lower temperature (Clausius, 1850). The entropy has been applied in the field of information theory, beginning with the work of Shannon who introduces the concept of information as a measurable quantity.

O'Connor (1991) states that a necessary condition for the definition of a system (e.g., the system of an organization) is the existence of information. In this context, the study of entropy can be useful to analyze its impact on the organization of the company' system. It can be also observed the entropy appears in the processes and activities inside an organization, as a consequence of scarce information (Tejeida, 2005). This is an important aspect for the management of organization since the adding of information to any process or activity leads to better organize the elements of the several systems of organization.

According to the systems theory, based on the relationship between system and the environment, there are two types of the systems: open and closed systems. It is considered closed systems when there is no interaction between them and environment. That means no types of transfers in or out of the system have been produced. The open systems are more complex since they strongly interact with the environment, transferring certain types of elements. This interaction generates a lot of changes on the function of any elements or on the entire system (Wang, 2004). Organizational systems are open systems, including different factors, processes, and activities which are correlated through causality relationships, acting to achieve specific goals. In this context, the elements of the system (e.g., people, purposes, technologies, information) must be integrated by the managerial system to ensure the best value for the organization (Montuori, 2000). Moreover, a fit between the organization and its environment is needed, in order to increase the organization's capacity to ensure an equilibrium state concerning the repeated cycles of inputs, transformations, and outputs.

Information is one of the most important elements that organization disposes it, both as input and as output (Castells, 2010). In this case, the amount of information that exists in the organization system gives the degree of its disorder, or of its entropy. Generally, the entropy means disorder, reflecting the progressive loss of the potential for energy transformation inside a system (Farazmand, 2003). Observing the organizational system, Ben-Naim, (2008) states that entropy and information are strongly related, highlighting that entropy is synonymous of lost information. Considering organization as a dynamic and complex system it is relevant to analyze the information entropy, which can modify the organization's cycle of development. As an Information theory concept, the information entropy describes how much information there is in an event, which appears in a system with a certain probability.

New Economy, based on information technology, requires information with a necessary volume and quality that allows organization to manage the changes coming from an environment where competition is increasing (Cao and McHugh, 2005). Usually, this information is unpredictable and unavailable, which generates stochastic functioning of socio-economic system, expressed by the concept of information entropy. Heylighen and Joslyn

(2001) take entropy and information in their complementarities, underlining that they are perhaps, the most fundamental quantitative measures in cybernetics. According to them, entropy is a probabilistic measure of uncertainty or ignorance; information is a measure of a reduction in that uncertainty.

Starting from the principles of the second law of thermodynamics, and considering the developments in information theory, the extrapolation of entropy phenomenon to the behavior of socio-economic system (e.g., organizational system) allow identifying the specific relationships between information and entropy. Whether in the thermodynamic systems the entropy describes the equilibrium state of a thermodynamic system, in case of socio-economic systems the entropy determines the degree of internal disorder (Markina and Dyachkov, 2014). One of the challenging directions in the organizational research is based on use the information entropy as a guide for determining the structure level of the organization's system. It is well known that information has a non-entropic nature. That means that more information the system has, less entropy is produced. By using the principles of systems theory, and also of information theory it can be analyzed the behavior of organization's system in terms of entropy and information.

In order to evaluate the information entropy of an organizational system it should be consider that the amount of information related to any *experiments* produced inside the system define its specific state (i.e., order, disorder, chaos and uncertainty). An experiment is characterized by a number of *events* (or outcomes), which are occurred with a certain *probability*. To formalize these concepts, the following notations are used:

X – the random experiment
$x_1, x_2,\ldots,x_n$ – the events (outcomes) of the experiment
$p_1, p_2,\ldots,p_n$ – the probability of occurrence of each event

It is noted that each value of X, (x_i), represents an event with a corresponding probability of occurrence, p_i. This probability can be interpreted as a measure of uncertainty about the occurrence of the event. If p_i is low, then it is expected that any events or all, will not occur. In this case, the realization of the experiment is highly uncertain, because of lack of information.

After completing the experiment X, which assumes the achievement of the x_n possible events, the amount of information is increased in proportion to the probability of their realization, reducing the initial uncertainty of X. As Singh (2013) observes, the measure of uncertainty should be based not on the occurrence of a single event of the experiment but of any event from the collection of all events whose union equals the experiment. He continues by defining the entropy as the measure of uncertainty about the collection of events (Singh, 2013).

Thus, in information theory, the more frequently form to define the entropy of a random experiment X, which has a number of events (n) and probabilities of occurrence (p_i) is (Ghahramani, 2006):

$$H = -\sum_{i=1}^{n} p_i \log_2 p_i , \qquad (1)$$

Where:

n - the number of events
pi - the probability of occurrence of each event

The unit for the amount of information is called *bit* (binary digit). For any process conducted within the organization's system it can be quantified the amount of information obtained through its realization that makes possible to determine the level of information entropy.

Understanding the law of entropy it is critical for business in terms of relationships, structure, processes, organizational culture, and controls. The effect of increase entropy is analogous with disorder in a business system. Deterioration is related on many aspects of a business system including people, processes, and technologies. According to Alcedo (2011), the presence of business disorder (i.e., entropy) can not sustain the quality and competitive price of products and services. Despite the fact that entropy is difficult to interpret in business systems, many researchers propose studies to evaluate entropy in organizational systems (Martínez-Berumen et al., 2014; Nemetz, 2013).

3. RESEARCH METHODOLOGY

Starting from the research problem related on how information entropy affects the state of the organizational system a qualitative approach is used. This approach is based on observational methods, which are heavily used in social sciences, and behavioral studies. One of the most common methods for qualitative research is case study, used to describe certain phenomenons in the context in which they occurred.

The case study is focused on the description of experiments that are produced in organization (i.e., business company, public institution, state-owned companies), the events which are possible to occurring inside the experiments, and the probabilities to happen of each of these events. In particular, a plan for the case study was done, as follows:

a) *Defining the experiments*

In this phase, the observation method is looking at certain processes and activities that are relevant experiments, leading usually to the entropy processes (management, innovation, communication, strategy, organizational culture). Thus, the focus area is the selection of these processes or activities which are frequently exposed to give away part of information, because of different influence factors that are uncertain and vague.

b) *Identifying the set of events for each experiment and the influence factors of these events.*

Any experiment assumes a set of events for its producing, and certain factors that lead to the probability of occurrence of each event. The more the factors can be precisely quantified, the more the probability of the event occurrence has a value close to 1. That means the amount of information of a particular event is a function of the probability of that event. The more unlikely an event, the less information there is.

c) *Computing the Shannon entropy* for the experiments which are selected to research. The relationship between information entropy and the organization level of the innovation process have been analyzed.

To study entropy in the field of information theory, several models has been elaborated, such as: Shannon entropy (Shannon, 1949), exponential entropy (Pal and Pal, 1991), epsilon entropy (Rosenthal and Binia, 1988), algorithmic entropy (Zurek, 1989). For this study, the Shannon entropy is used, in order to understand how the entropy process affects the

organizational system. Based on the proposed methodology, the next section presents a case study in a Romanian company, in order to analyze the information entropy and its impact on organizational system state.

4. CASE STUDY

Starting from the environmental challenges in the energy sector, a Romanian state-owned company has been selected to analyze the influence of information entropy on the organization level of company system. It is noted that there are important organizational processes that might produce different form of disorder in the company's system, which may be translate into malfunctions, such as incompetent decisions, disaffected employees, underperforming leadership, strategic inertia or inefficient internal communication. All these forms of disorder are generated by a progressive loss of the information, which describes the structure and the functions of the processes.

Based on the above methodology, the following processes (i.e., experiments) were selected, in order to assess the organizational system entropy (Table 1):

Table 1. Organizational processes (experiments) exposed to information entropy

Process (experiment)	Description
Management process	Set of structures, functions and relationships established with the aim of decision making, based on information resource.
Innovation process	Process that allows the implementation of new goods, services, and new technologies, based on the access and exploitation of information and knowledge.
Information and communication processes	Technologies, practices, and infrastructure that allow data processing for the organizational processes.
Business strategy	Definition of the strategic direction, objectives and the actions needed to achieve them.

Source: Authors

It is considered that the state of each of the above experiments depends by the average amount of information, obtained through the producing of a set of events, which have a probability of occurrence. Therefore, defining the set of events for each experiment and the influence factors of these events is needed. It should be mentioned that in principle, the number of events corresponding to each experiment can be infinite. However, as shown in Table 2 we consider a finite number of events (e_i) which describe each experiment (X), and the probabilities of occurrence (p_i). In the other words, it can be noted as follows:

X – the random experiment or the random variable
$P = \{p_1, p_2. \ldots p_n\}$ – the probability distribution of n events of the experiment X
x_i – the event of the experiment X, where i= 1,2, …n.

Table 2. Set of events for the experiments and their probabilities

No. exp	Experiment (X)	Included events (x_i)	Probability (p_i)
1.	Management process	Understanding and analyzing the key performance indicators for the organization.	p_1
		Using the management information system for decision making.	p_2
2.	Innovation process	Developing new technologies to reduce the loss in energy transport network.	p_1
		Implementing projects to reduce the impact on environment.	p_2
		Promoting the renewable energy in rural communities.	p_3
3.	Information and communication processes	Implementing information systems to support the core processes.	p_1
		Adopting new communication technologies.	p_2
4.	Business strategy	Collecting strategic information from the external environment using Economic Intelligence practices.	p_1
		Detecting opportunities and threats from the external environment to define the objectives of the strategy.	p_2

Source: Authors

The events that we considered in case of each experiment have a certain probability to occur, depending on the amount of information gained from inside or outside of the experiment. Based on the fact that entropy can be considered as a measure of uncertainty and also a measure for information (Singh, 2013), the question is how much of uncertainty was in an event, before its producing. The degree of this uncertainty will be reduced or removed through the increase of information's amount that leads to higher probabilities of occurrence for the events. Certainly, the problem of uncertainty is not only related on the amount of information, but also on its quality and pertinence.

In this case study we focused on the entropy of Innovation process, in order to measure uncertainty caused by the events that force this process to deviate from a regular behavior.

The Shannon entropy (Singh, 2013) is used to quantify the information gained by observing the join occurrence of the three events included in the selected experiment. Thus, the information entropy of Shannon is given by the equation:

$$H(X) = -k\sum_{i=1}^{n} p(x_i)\log[p(x_i)], \qquad \sum_{i=1}^{n} p(x_i) = 1 \tag{2}$$

Where:

H(X) is the entropy of random experiment
xi, i=1,2,…n is the events of X
p(xi), i=1,2,…n is the probability distribution of the events
K is a parameter whose value depends on the base of the logarithm used.

According to this equation, the entropy reflects a measure of uncertainty of innovation process, given by the average amount of information which is gained by the process. This is important to know because, from a managerial point of view, reducing of uncertainty allows

the process to ensure more predictability. On the contrary, less information means high level of uncertainty that leads to more difficulties in the efficiency of the process.

The innovation process can be conceived as a system, including interconnected elements (e.g., activities, resources), which have an order set and a defined goal, and interacting with the internal and external environment of organization. In this approach, becomes relevant to analyze the relationship between information entropy of this process and its level of order/disorder.

The degree of order in the innovation process is given both by amount of information, and its accuracy, relevance, value, or precision. This suggests that information entropy is tightly related on the organization level of the process. There is an inverse correlation between them that is more order in the process (i.e., system) leads to reduced entropy. An interesting aspect is reported to the case of maximum entropy which is revealed when all the events of the experiment have the maximum uncertainty. The maximum entropy occurs when all the events occurs with the same probability, that means there are no constraints on the process (Singh, 2013). The entropy function attains a maximum, which is mathematically demonstrates as being (Singh, 2013):

$$H_{max}(X)=\log_2 n, \qquad (3)$$

Knowing the entropy (H) of the process selected, which is a measure of disorder and the maximum entropy (H_{max}) which expresses a theoretical limit state of the process it can be determined the process's degree of organization (S) to different moments of times (Ludovico, 2008):

$$S= H_{max} - H, \qquad (4)$$

Where:

S= syntropy (negentropy)
H_{max} is the maximum entropy
H is the entropy

The concept of syntropy is also used to express the negentropy as the indication for the order in a system (Ludovico, 2008).

To analyze the relationship between information entropy and the organization level of the innovation process it has been observed the probability distribution of the events that are included, on different moments of times. By using business improvement software (BSI Group), it was calculated the level of entropy (H) and the process's degree of organization (S), in order to reveal the correlation between them (Table 3). According to equation (3), the maximum entropy for the experiment which was selected is H_{max}=1.58.

Table 3. The values of entropy and negentropy for the Innovation process

Time (t)	**t_0**	**t_1**	**t_2**	**t_3**

Probability (p_i)				
p_1	0.47	0.31	0.33	0.28
p_2	0.34	0.25	0.33	0.21
p_3	0.19	0.44	0.33	0.51
H (entropy)	**1.50**	**1.54**	**1.58**	**1.48**
S (negentropy or process's degree of organization)	**0.08**	**0.04**	**0.0**	**0.1**

Source: Authors

Analyzing data in the Table 3, it can be observed that at the moment t_2, the maximum entropy is occurred. Thus, the uncertainty of information is maximum that leads to maximum disorder of the process. The biggest level of the process's organization is obtained at the moment t_3**,** when the lower limit of the values the entropy function was assumed.

It must be noted that, to ensure a high level of order in case of socio economic processes, which are considered open systems in terms of system theory, control measures are required. These might be certain actions that lead to reduce or eliminate the higher risk resulted from the uncertainty and the loss of information. However, any system tends to its most likely state, which is contrary to the order established by the structure (i.e., the disorder) (Martínez-Berumen et al., 2014).

The assessment of the entropy related to innovation process can be employed to consider the behavior of this process under the influence of the amount of information. It is important to note that many factors affect the outcomes (i.e., the events) of the process, such as: people, management of the process, communication, organizational integration, and so on. Often, these factors work through enhancing the information which is needed to reduce the fluctuations that could disturb the process.

4. CONCLUSIONS

Although the origin of entropy is founded in the law of thermodynamics, the study of this concept in the information and communication area become relevant with the study of Shannon in his Information theory. The implication of determining the entropy level is important for organization, either in business environment, or public administration sector. Information entropy is related on the amount of information that supports the organizational system. To increase these information the events that occurs in internal and external environment of organization must be produced with high probabilities. Thus, if the information entropy is high, that means is not enough information to ensure the evolution of the system towards higher order levels. On the contrary, the low level of entropy shows that the organizational system has greater order (determined by the acquisition of information), allowing to adapt on the changing conditions.

In most managerial circumstances the entropy can be used as an indicator of the efficiency and performance. By identifying the processes which have high entropy on the certain period of time it can be adopt the measures to ensure that the organizational system evolves towards higher-order levels.
Starting from these statements, this study presents the concept of information entropy and its application on the innovation process, which is considered to be more exposed to this phenomenon. The research reveals the relationship between information entropy and the

organization level of the innovation process. Based on the empirical data, the findings showed the moments when have been obtained the maximum, respectively the minimum level of information entropy.

This paper is mainly focuses on the description of the conceptual framework of information entropy. Future researches will develop a pilot investigation to evaluate the entropy of the organizational system as an indication to assess its behavior in the contemporary environment.

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