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Sustainability and Safety: The Complex System Properties

Afgan, H., Naim; and Carvalho G., Maria

Abstract– ***In the assessment of long term behavior of the complex system we introduce the notion of sustainability as the measure for the quality of the system. It is defined as a new quality which is measuring the ability of our society to secure and not compromise the ability of future generation to have quality of the life at least the same as our generation. This definition is a new approach to the definition of the comlex system property.***
The safety property of complex system is immanent to any system. It reflects quantitative merit for degradation of the system. Also, it includes rate of changes for any process leading to degradation of the system. Environmental degradation is among the most pressing global issues confronting modern society.
Sustainability and safety are linked with the similar essential idea to prevent degradation of the quality of the system. The sustainability is defined as the aggregation function of physical, social, technological, environmental and resources parameters. The safety is time derivative of the sustainability index. It was shown reference example of application of the multi-criteria evaluation with Sustainability and Safety Indexes of complex system. In conclusion, the evaluation of complex system is involved in the sustainable development research with associated uncertainty.

Key words–***complex system economic, environmental, technological and social indicator, indexes, multi-criteria evaluation, resource, safety, sustainability***

1. INTRODUCTION

The paper is an attempt to introduce the sustainability definition in the evaluation of the complex systems. By the introduction of sustainability notion as the proprety of the complex system a new approach is developed and applied in the selection ana assessment of different systems.

The vulnerability of modern world is an important issue to our humanity. For this reason it is of great importance to understand the state of system which may lead to the hazardous degeneration of any life support systems [1]. We now live in the world with treats that most of our sophisticated man made systems may become source of the hazardous species which may effect human lives. Fundamental safety consciousness is a challenge for understanding the need for the development of appropriate methodology for the assessment and evaluation of potential standard for safety. We are witnessing everyday that the safety notion is a key issue in human life. It has effects with individual and collective consequences in long term and short term span of time.

The development of sustainability science has become ultimate goal of modern society [2]. Like any other knowledge the safety science is cumulative resource of human history. Number of hazardous events is increasing which may be justified as consequence of the need for the better understanding individual events as much as the notion of collective properties of life support systems. It is immanent to any life support system to be described with the respective properties representing collective set of individual indicators. Relation between the safety properties of complex system and any other property of complex system is the fundamental quality indicator of the system..

In the assessment of long term behavior of the system we have to introduce notion of the sustainability as the measure for the quality of the system.[3,4] It is defined as the quality which is measuring the ability of our society to secure and not compromise the ability of future generation to have quality of the life at least the same as our generation. This measurement is aimed to facilitate control of the steady state of our systems. The safety of any system is closely linked to the change of quality of the system. It is known in thermodynamics that any change of the entropy of the system is directed to its maximum. If we look at the global scale of complex systems the maximum entropy will mean the death of the system. If we consider complex system defined with sustainability as the indicator of its quality, it is logical to assume that the time change of sustainability of the system may be used as the measure for the potential changes of safety of the system. Even it was accepted that present science is not in position to allow us to explain or model the complex system in the world, in the past number of years the attention was focused to study phenomena that seemed to be governing the spontaneous appearance of novel structure and their adoption to the changing environment [5]. Most of the life support systems

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are convoluting to the formation of the new structure and require a new approach in the evaluation of the system. The complexity of the systems is increasing in current decade.. There are many reasons. Among those are: ontological changes, epistemological changes and changes in the nature of decision making.. Sustainability development requires integrating economic, social, cultural, political and ecological factors. From the scientific viewpoint there are two basic task: one is the identification and understanding of the most important is the linkages between different factors and different scales that originate the possible changes in one component of the system into other parts of the system. The other task understands the dynamic of the system.

Environmental degradation [6] are among the most pressing global issues confronting modern society. Investigation of the potential capacity of the complex system to cause environmental degradation is an important goal of modern science. The study of these problems has imposed the demand for the assessment of safety properties of complex system [7]. In this respect definition of the safety property of the system is the essential parameter which define the adaptability of the system to its surrounding. Since sustainability of the complex system is by itself its property of the system, it is acceptable to take the sustainability change as the property indicator for the safety of the system.

Sustainability and safety are linked with the similar essential idea to prevent degradation of the quality of the system. As sustainability is defined as the aggregation function of the physical , social, technological, environmental and resources parameters it can be defined that the safety is time derivative of the sustainability indicators. Abrupt change of the sustainability will lead to the disastrous degradation of the system. Similarly, it can be taken that any adverse change in the sustainability indicator as the respective measure for the safety degradation of the system.

2 SUSTAINABILITY

Sustainability comprise complex system approach in the evaluation of the system state. By its definition sustainability include definition of quality merits without compromising among different aspect of system complexity. It is of paramount importance for any system as the complex system to quantify elements of complexity taking into a consideration various degree of complexity. As regards complexity elements of the system it can be codified as the specific structure reflecting different characteristics of the system .

Any process is characterized by the entropy production as the measure of the irreversibility of the processes within the system.. So, the complexity element of the system is reflecting internal parameter interaction can be defined by the entropy production in the system.. In the complexity definition of system one of the element is entropy generation on the system or energy losses in process [8]

Complexity elements of the economic indicators are structured in different levels are intrinsic to the specific levels and are measured in different scale. In the classical evaluation of system the economic merits are of primary interest. Since the economic quality is reflecting optimization function imposing minimum finale product cost , there are a number of parameters which are of interest to be taken into a consideration in the mathematical model for the determination of the optimized values of required for its evaluation .

Mutual interaction between the system and its surrounding is immanent for any life support system. As it is known the system is taking material resources from the surrounding and disposing residual to the environment. Among those residuals are the most important those which are in gaseous form and are dissipated to the environment. Also, most of the energy system is disposing low entropy heat to the environment

The social element of complexity of the system is property of the complex system.. In the social aspect of the system is included risk of environmental changes, health and nuclear hazards and may have to deal with a compounding of complexity at different level. Also, under social constrain reflecting social aspect of complexity of energy system are added values which improve the quality of the human life.

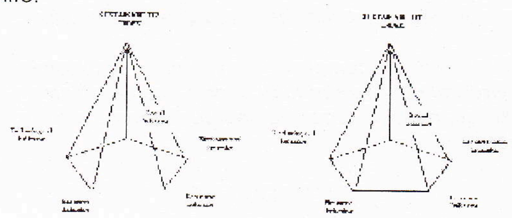

Fig. 1 Sustainability Index Structure

The technology quality of the system is the element of the complexity of the system. It may be defined and qualified as the potential upgrading of the individual part of the system and also as the interrelation among the elements. In the language of complex system this property can be understood as the inherent creativity of spontaneous appearance of novel structure.. Thermodynamically, information introduced in the system is the negentropy as the result of the

change in the structure of system leading to the better performance .
Fig.1 shows graphical presentation of multidimensional Sustainability Index which is expressed as the additive function of the indicators multiplied by the respective weighting coefficients.

3. SAFETY

In the decade from 1991-2000, natural disasters killed a reported 665,598 people, probably an underestimate. And every year over 211,000 people are affected by natural disasters - two-thirds of them from floods. The number of weather-related disasters (droughts, floods and storms, for example) has doubled since 1996 while the number of geophysical disasters (e.g. earthquakes and volcanic eruptions) has remained steady over the last decade. And while floods cause the most damage, earthquakes run a close second, causing nearly US$270 billion of damage in the decade from 1991-2000.

The risk of natural disasters is often known and some preventive measures can be taken to protect human life, using selected materials and practices for building, avoiding flood-prone areas, etc. But it is often impossible to protect historic monuments from damage. Local authorities might also draw up a disaster action plan that could include briefing emergency services on how to limit the damage.

The safety of complex system property is immanent to any system. It reflects quantitative merit for the degradation of the system. Also, it includes rate of changes for any process leading to degradation of the system. It may be seen as the potential property predicting total degradation of the system. It is commonly known that any degradation of the system precede with the changes of the main properties of the system. Since sustainability is a complex property of any system the description of the sustainability change in time scale will lead to the possibility to define those rates of changes which may have different consequences. There are different disasters which are reflection of the specific causes. [9].

Taking into a consideration the change of individual elements of complexity we can design quantities which are of importance for definition of the potential states leading to the degradation of the system. In this respect we can analyze all elements of the complexity of the system and their change in the time scale.

Any process in the system is characterized with the entropy production as the measure of the irreversibility of the processes within the system.. The stationary state of the process is characterized by the constant entropy production[15] Non linearity of any process leads to the very fast degradation of the system. Typical example of this type of process is explosion. So, the rate of changes of entropy production in the system can be taken as the characteristic quality of the system which describe safety of the system.

The change of economic elements of indicator is intrinsic to the specific characteristic to be measured in the time scale. The time change of the economic indicators is common to the classical evaluation of system.. Any crises of the economic system is preceded with corresponding changes in the economic indicator of the system. Qualitative measurement of these indicator changes may lead to the forecast of the economic crises which is only one element of the potential disastrous changes of the system effecting its safety. Fig. 3, shows schematic presentation of Safety Index.

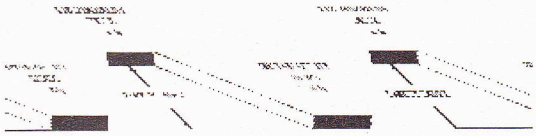

Fig. 2 Schematic presentation of Safety Index

The mutual interaction between the system and its surrounding is immanent for any system. The changes in the interaction rate will effect the safety of the system... If this processes are in steady state it can be considered that the system safe.. As good example for this type of changes of indicators is the interaction of the system and its surrounding in the case of radioactive leaks from the nuclear facilities, which may lead to the hazardous consequences.

The change of social element of complexity of the system is property of the complex system.. The social aspect of the system includes the risk of environmental changes, health and nuclear hazards and may have to deal with a compounding of complexity at different level. It is of interest to notice that some of the social changes are an inherent characteristic of the system. As example we can take any strike which is result of the economic changes of the system. Similar example can be seen if there is sudden change in the environment which will lead to the social disturbance .

4. MULTI-CRITERIA EVALUATION OF SUSTAINABILITY AND SAFETY

The complex system requires special methodology for the evaluation. Since complexity of the system is closely related to the multi-dimensional space with different scale, the methodology has to bear multi-criteria procedure in evaluation of the complex system.

The method for multi-criteria evaluation and assessment of complex system has proved to be promising tool for the determination of quality of the system. Even it was shown that there are some deficiencies in the presented method , it is a new route in tracing future analysis of complex system.

Sustainability comprise complex system approach in the evaluation of the system state. By its definition, sustainability include definition of quality merits [10,11]. It is important for the assessment of any complex system to quantify elements of complexity taking into a consideration various degree of complexity. The complexity elements of the system can be codified as the specific structure reflecting different characteristics of the system [12,13]. It should include description of the interaction of internal parameters of the system and the system interaction with the different aspect of socio-economic-environment of ecosystem. The adoption of system to its surrounding leads to the physical, social and environmental interaction between the system and its surrounding. If there are number of different systems to be compared taking into a consideration potential behavior of individual system in the same surrounding there must be potential option which will give quantified quality priority among the system under consideration.

In order to define quantities which are used as measuring parameters in evaluation of the systems a following definition of qualities are adapted [14]:

1. Resource quality
2. Environment quality
3. Technological quality
4. Social quality

4.1 Resource Quality

Complex system is composed of number of elements which are connected with the aim to perform specific function,. The organization of the system elements is reflecting optimized structure of the system following specific pattern. The material conversion characterization is thermodynamically justified process with optimal internal parameters of the system. In this respect the quantification of thermodynamic quality of the system is reflecting number of parameters which are defining the design of the system.. Otherwise, it can be stated that the complexity element of internal processes in the system can be defined as the quality of material conversion measured by the thermodynamic efficiency of the system or any other parameter including integral parameters of thermodynamic system [15]. The material conversion process is characterized by the entropy production as the measure of the irreversibility of the processes within the system. So, the complexity element of the system reflecting internal parameter change and can be defined by the entropy production in the system [16]. Lately it is becoming popular to make energy analysis of the system as the tool for the quality assessment of the system as whole and also determine energy losses in individual elements of the system [8]. In this case the complexity element is entropy generation on the system or energy losses in conversion process.

4.2 Economic Quality

Any complex system evaluation has to include economic validation of the product and it has to be the basic building block of the assessment procedure [17]. Also, it is indispensable element of the complex system. The quality of complex system has to comprise the economic validation of the system. as the element of complexity. The main characteristic of the economic quality of the system is defined by the parameters comprising individual sub-elements of complexity reflecting economics of the system product. It is usually accepted to determine the economic indicator as the reflection of those sub-elements of complexity which are in the different scale. For this reason formation of fuzzy set of indicators for the consideration of energy system options is not trivial and has to reflect different conception of the system. Complexity elements of the economic indicators are structured in different levels are intrinsic to the specific levels and are measured in different scale. Since the economic quality is reflecting the optimization function imposing minimum finale product cost , there is a number of parameters which are of interest to be taken into a consideration in the mathematical model for the determination of the optimized values required for its evaluation [18].

4.3 Environment Quality

Mutual interaction between the complex system and its surrounding is immanent for any life support system [19]. For the complex system there are number of interaction which are defined by the respective parameters. On the first place, these interactions are the effects of system on the environment. As it is known that every system is taking material resources from the surrounding and disposing residual to the environment. Among those residuals are the most important those which are in gaseous form and are dissipated to the environment. Also, most of the complex systems are disposing low entropy heat to the environment. So the interaction between the system and environment is defined by the amount of material and energy transferred. The assessment of these interactions between the system and environment leads to recognition of the new element of complexity of the system. The basic components of environmental complexity element will be used in the assessment of the quality of individual system among the number of options under consideration. Every complex system is entity with the strong interaction with environment. There are ontological changes i.e human-induced changes in the nature proceeding at unprecedented rate and scale and resulting in grooving connectedness and inter dependency. Molecules of carbon dioxide produced in the energy system leads to the global climate changes and adding new element to the complexity of energy system.

4.4 Technological Quality

The complex system structure organization is subject to the constant development in order to improve its functionality and performance quality.[20]. The adoption of the system to the new requirement is complementary to the organization changes as the property of the complex system. The assessment of technological development implies adaptability of complex system to its evaluation. Information technology has demonstrated that its application to any system can lead to the intelligent system with self controlling ability. The potentiality for further improvement can be seen as the potentiality for self-organization of the system. This can be achieved with the use of information knowledge, organization and also introduction of new processes. It may be defined and qualified as the potential of the individual part of the system and also as the interrelation among the elements. In the language of complex system this property can be understood as the inherent creativity of spontaneous appearance of novel structure. Thermodynamically, information introduced in the system is the negentropy as the result of the change in the structure of system leading to the better performance [22].

4.5 Social Quality

Social aspect of the complex system is important factor to define the quality of the system. Beside the adverse effect of the system on the environment, there may be another driving force for the social changes in the region [21]. It can bring new jobs, new investment, new infrastructure and many other advantages in the region. This quality of the system must be defined as the elements of the complexity of the system. The interactions of the system with society are properties of the whole, arising from the interactions relationship among the system and surrounding. With a number of options under consideration the social element of complexity of the system will comprise integral parameters and their evaluation. The social aspect of the system includes risk of environmental changes, health and nuclear hazards and may have to deal with a compounding of complexity at different level. Also, under social constrain reflecting social aspect of complexity of system are added values which improve the quality of the human life .

5. INDICATORS

In order to develop appropriate tool for the quality presentation of complex system, it is of interest to introduce the notion of the indicators which are measuring parameters of the respective quality [22]. Before, we will introduce individual indicators the agglomeration procedure is described.

5.1 Hierarchical Concept of Indicators

As it was shown different complexity elements are expressed as the integral property of the system. For the determination of these elements respective model are used based on the mathematical description of the processes within the system.

Recently it has become necessary to make assessment of any system taking into a consideration the multiple attributes decision making method. It has been exercised in the number of cases the evolution of systems with criteria reflecting resource, economic, environment, technology and social aspect [23, 24, 25]. A complex (multi-attribute, multi-dimensional, multivariate, etc.) system is the system, whose quality (resources, economics, environment, technology and social) under investigation are determined by many initial indices (indicators, parameters, variables, features, characteristics, attributes, etc.). Any initial indicator is treated as the quality's, corresponding to respective criteria. It is supposed that these indices are necessary and sufficient for the systems' quality estimation [26].

An example of graph-representation of a 2-height pyramidal hierarchy of indices is pictured on the Fig.4.

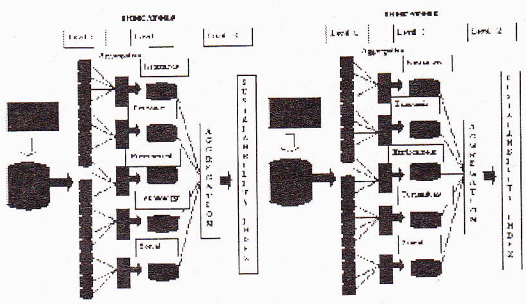

Fig.3 Graphical presentation of the algorithm for the sustainability evaluation of complex systems.

5.2 *Safety Index*

If it assumed that the sustainability indicator is time dependent function, we can take predefine time increment and determine Sustainability Index at the beginning and the end of the time increment. In Fig.5 is shown the block diagram of Safety Index

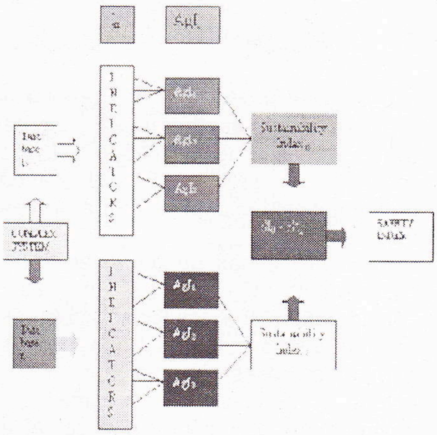

Fig.4 Block Diagram for Safety Index

In this respect we can form respective data bases reflecting individual values of the indicators for the specific time.. Following the same procedure for the Sustainability Index Increment for the specific time increment we will obtain change in the Sustainability Index as measure of the Safety Index. If this procedure will be applied for the different time increments the results obtained will give us possibility to justify Safety index as the property of the complex system. Introduction of block diagram is aimed to show the procedure for the definition and determination of the safety index. As it can be noticed the first step in this procedure is to define an increment of time for the collection of the basic data to be used in determination indicators. The safety in complex systems is an open question. We have described one approach to achieving this goal that has been demonstrated on several real systems, including :energy environment and water systems [28]. Safety, however, is not something that is simply assessed after the fact but must be built into a system. By identifying safety-related requirements and design constraints early in the development process, special design and analysis techniques can be used throughout the system life cycle to guide safe software development and evolution.

CONCLUSION

As the conclusion of this paper it can be emphasized following :

- it was shown that the sustainability index is the relevant property of the complex system to be used in evaluation of complex system
- definition of the sustainability index as the e conomic, en vironment, technological and social quality is verified as the property of the system
- the time change of t sustainable index is verified as the potential tool for the safety index for the system under evaluation

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