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MEASURING THE RISK OF ECOLOGICALLY DANGEROUS ECONOMIC ACTIVITIES

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Abstract

The present study reveals and defines a procedure for risk measurement that reflects precisely and thoroughly the threats to the environment caused by economic activities. The paper explains the logics behind the risk measurement. It works out a measurement procedure and shows arguments for the operations, the measurement values and the measurement units. The way for defining the numerical values of the risk is also presented.

Key words*: measurement, risk, environment, economic activity.*

INTRODUCTION

The economic activities according to the classification KID-2008 cover practically all human activities and the activities of the society as a whole. They are related to generating phenomena dangerous to the environment both directly and indirectly. Each human activity brings a potential risk to the environment. This statement is based on the fact that even ecologically safe at first sight productions have sources generating ecologically hazardous factors.

The aim of this study is to give reasons for a risk-measuring procedure, which reveals precisely and thoroughly the threats to the environment caused by economic activities.

In order to achieve this aim the following tasks are solved: 1) Eliciting the logics of risk measurement; 2) Developing a measurement procedure; 3) Determining the numerical values of the risk.

ARGUMENTS

The risk is a criterion for the threats to the environment generated by economic activities.

Defining ecological safety of economic activities requires measuring the risk of the impacts on the environment. Firstly, the risk helps us to determine the ecological criticalities and the ecological insecurity, and then the ecological safety [2].

Measuring the risk for the environment caused by economic activities is based on five principles:

1. The Principle of Hierarchy. It consists of defining the risk as a value which is decomposed in a tree-like structure. It describes the risk by a combination of specific, lower components moving to general, higher components.

2. The Principle of Integrality. Measuring the risk as a whole is a process of defining the integral risk reflecting the risks of dangerous phenomena arising, as well as dangerous activities and dangerous effects.

3. The Principle of Zero Dimensionality. It can be observed in defining the components of the integral risk in zero dimensional values. On the one hand, the principle allows us to recognize the specific diversity of risk factors and, on the other hand, to receive compatible from dimensional point of view values of the risks present.

4. The Principle of Equivalency. It is found in accepting that the components of the integral risk at a certain hierarchical level have an equal degree of significance.

5. The Principle of Cause-effect Relationships. It is represented in determining the risk as a totality of conditions, circumstances and processes related via «cause-effect» relationships.

The risk of the economic activities to the environment corresponds to specific systems, which while functioning generate threats. That requires an initial description of the systems with all their composite parts and the interactions between them, on the one hand, and with the environment, on the other hand. At this stage, the risk factor is determined for each element, as well as its level, the conditions for the emission distribution and the emissions themselves.

Methodologically, the description of the economic activities and their aspects of influence on the environment are presented in detail in [1,5]. We built polysituational models which represent potential situations of ecological threats.

Risk measurements are based on monosituational models of the risks which are generated in the systems [2]. The models of the monosituational risks are an objective taxonomic consequence of polysituational models. We define [1,2] six conditions for the rise of environmental threats and risks: 1) Dimensional compatibility of the object of influence-the recipient and the risk factors in the area of their distribution; 2) Levels of risk factors and their deviation in relation to the marginal permitted values; 3) Time compatibility of the recipient and the risk factors; 4) Exceeding the permitted time for the recipient’s stay in the area of the risk factors; 5) Matching the time of activity and the time of exceeding the marginal values of the risk factors; 6) Compatibility of the polysituational risk model and the appointed measurement aims and tasks, the structure and content of the elicited threats.

We consider the transformations and the characteristics of the risk as measurement values. They have to be presented thoroughly, the subject evaluating them has to perceive them and they have to be standardized by ascribing specific numerical value to them. The measuring values have to be defined correctly. The measurement units need to be compatible and in accordance with the values.

The amount of the risk is a ratio of the measurement values to their standards which are different along the axis of the temporal risk R_{Tind}, of the indicator risk R_{ind} and of the componential risk R_{komp} [2,5]. Therefore, it is required that we should define: 1) the measured characteristics quantitatively and qualitatively, and their corresponding risk measurement values; 2) the measurement units; 3) the principles of measurement; 4) the methods of measurement; 5) the procedures of measurement.

The measurement along the axis R_{ind} is necessary because the risk values R_{ind} represent the progress of the threat at a lower level. The measurement values along the axis R_{ind} correspond to the three components of the threats. Consequently, three types of risks are considered – caused by dangerous phenomena $R_{ind_{Fen}}$, by dangerous activities $R_{ind_{Act}}$ and by dangerous effects $R_{ind_{Eff}}$ [2]. Their measurement is carried out by finding out the values of the indicator risks. They determine the transfer of one element into another, from one state into another. Thus, we define the causes and effects of risk transformations.

The vertical decomposition of the risk is hierarchical [2]. The measurement along the axis of the componential risk R_{komp} is necessary because the measurement results allow us to define the relative shares of the factor values, firstly in the indicator risks and then in the componential risks. The amount of the risk R_{komp} reflects the nature of the threat to the environment. It follows the logics and the indicators for the progress of the threats. The measurement values are in four levels. Although they relate to one and the same measurement value, the amounts of the risks along the axis R_{ind} differ from those along the axis R_{komp}. The difference is in their nature. The risks along the axis R_{ind} represent the elementary transformations of causes into an effect, while those along the axis R_{komp}- represent the phase transformations.

The measurement along the axis R_{Tind} shows the dynamics of alteration of factor values, indicator, componential and integral risks. It allows us to measure their values in different sections of time.

The amount along the axis of the temporal risk R_{Tind} is a value we use to define the area of criticalities and their centres. It appoints the temporal values of the risks. The values along the axis R_{Tind} are indiscreet, which is due to the nature of defining the factor of time when a risk arises. They are probabilities for the appearance of temporal moments or temporal intervals with fixed values and they change from 0 to 1.

For the environmentally dangerous phenomena the measurement value is the number N_{NEE}, N_{OPE}, N_{CAUSE} of the cases of a specific cause, operation, activity arising during the studied period of time *T*. An additional measurement value is the duration ΔT_{NEE}, ΔT_{OPE}, ΔT_{CAUSE}. They can be equal to the total time *T* of measurement but they can also be a part of it.

The source of generating dangerous factors – the stressor is analogous in nature and it is a measurement value represented by N_{SOURSE} and ΔT_{SOURSE}, respectively. Their significance is fully identical with the significance of the cause. The risk factor corresponds to the nature of the factor values. It can be of physical, chemical, biological, psycho-physiological and hybrid nature. Its name and description are of non-metrical character but when we introduce the number N_{FACTOR} of the cases when it arises and of their duration ΔT_{FACTOR} it turns into a metrical random value. The risk factors and their levels are values that are measured in quantitative measureable units. Using the newly developed method for evaluation of the risk factors [2,4] we proceed to unified measurement values by introducing one-sided or two-sided limit of deviation.

Measurement values for the emission could be the number N_{EMISS} of emissions in a certain range of their probable values and the emission duration ΔT_{EMISS}. The measurement values for the emission levels are the number N_{EMLEV} of exceeded permitted values and the duration ΔT_{EMLEV} of the exceeding. The same way we introduce the measurement values and their corresponding measurement units for: 1) distribution medium - N_{MIDD} and ΔT_{MIDD} ; 2) an area of compatibility of the object and the region of immission distribution - N_{IMLEV} and ΔT_{IMLEV}; 3) immission - N_{IMISS} and ΔT_{IMISS}; 4) immission levels - N_{IMLEV} and ΔT_{IMLEV}; 5) time of polluting immissions - N_{IMTIME} and ΔT_{IMTIME}; 6) an object of impact - N_{OBJECT} and ΔT_{OBJECT}; 7) contact places N_{CONT} and ΔT_{CONT} ; 8) a type of damage - N_{TYPE} and ΔT_{TYPE}; 9) an aspect of the damage N_{ASPECT} and ΔT_{ASPECT}; 10) damage localization - N_{LOCAL} and ΔT_{LOCAL}; 11) a degree of the damage - N_{DEGREE} and ΔT_{DEGREE}; 12) compensation N_{RECOM} and ΔT_{COMP}; 13) recovery - N_{RECOV} and ΔT_{RECOV}.

The measurement values suggested correspond precisely to the main formulations for structuring and the conditions for defining the risk for the environment [2].

The measurement principles are determined by the type of phenomena on which the specific factor values of the risk are based. Because of that the principles of the State System for Ensuring Unity of Measurements belong to a second group, an additional one to the principles of risk measurement.

Due to the nature of the measurement values three methods of measurement are applied: 1) A direct method when the value is measured by reading a measuring device. It is used when measuring emissions, imissions, space, time and other natural or anthropogenic values. 2) An indirect method. It uses analytical dependencies between measurement values of metric, non-metric or combined type. 3) A combined method which is a totality of direct and indirect methods.

The measurement procedure consists of four stages: I-measuring the indicator risks along the axis R_{ind}; II-measuring the temporal risks along the axis R_{Tind}; III-measuring the componential risks along the axis R_{komp}; IV-turning to united non-metrical values.

The transfer to non-metrical values is carried out as follows [1]:

1) N and ΔT are analyzed as random values. The rule of distribution is determined by taking into account their character - discreet or indiscreet. We use in our experiments the software *Risk 4.5, Razpredelenie 2.0, Entropia 1.0, Statistica 8.0, SPSS 15.0, Statgraphics Plus 7.0.* For the discreet values we test the hypothesis of Poisson distribution, geometrical distribution, binomial distribution, hypergeometrical distribution, negative-binomial distribution, Bernoulli's distribution. For the indiscreet values we make a verification of the equal probability rule, the logarithmic-logistic distribution, gamma distribution, Pearson distribution, normal distribution, triangular distribution, beta distribution, Gumbel distribution, logarithmic-normal distribution, exponential distribution, Weibull distribution, Erlang distribution, logistic distribution, Wald distribution and Relay distribution.

2) We calculate the probability Pz_N for N values and the probability $Pz_{\Delta T}$ for arising of ΔT in the ranges $+\sigma > Ncp > \sigma$ and $+\sigma > \Delta Tcp > \sigma$ where Ncp and ΔTcp are the mean values; σ-mean-square deviation of measurement values. The second range of significance is from N_{min} to N_{max} and from ΔT_{min} to ΔT_{max}. This range is considerably wider, the probabilities Pz_N and $Pz_{\Delta T}$ are bigger, consequently the values of the risk increase. We consider it more appropriate because it takes into account the whole scope of deviation of measurement values.

In virtue of the presented basic assumptions the measurement of the risk could be generally defined as a system of operations for collecting, processing, generalizing and managing the risk information, as well as saving it on disks. There are complex straight and reverse relations and cycles between the separate operations. Measuring the risk creates integral information medium necessary for analyzing and evaluating the risk for the environment.

At the beginning the risk measurement is formalized according to the ecologically dangerous object. To accomplish this goal we define the studied system of economic activity. We specify its aim, tasks and structure. We determine the general and specific functions by taking into consideration the interactions in the system. Then a descriptive model of the threats should be made. It is a natural-language formalization of the scenarios for emergence and development of the risk and it is a requirement for reliability of the risk models' formulation. It directly influences the indefiniteness and vagueness of risk measurements.

The scenarios are modeled through polysituational models. It is suitable to collect the results in an information block. Taxonomic processing of the risk is carried out in order to find out the significant relationships between the elements of the polysituational models. These relationships are a sufficient condition for developing monosituational models.

The next stage consists of defining the factor values of the risk. Their nature and character determine the principle of their measurement - quantitative or categorical. The principle of measurement leads to the measurement methods - direct, indirect and combined. They form a database of knowledge about the measurement methods. The choice of devices for measuring the factor values is made on the basis of a comparative analysis of their basic meteorological characteristics. This requires information full enough about variants of measurement devices. Defining metrical factor values is related to performing a series of activities for determining the value. It is made by the chosen measurement devices. On the basis of the above-mentioned idea it is converted into a united non-metrical value. The conversion is done in parallel with the processing of the measurement results, irrespective of the character of the measurement values.

We perform the measurement operations of indicator and temporal risks successively. The measurement along the axis R_{ind} in function of R_{Tind} creates an area of points in their plane. The measurement along the axis R_{komp} is represented by calculating the componential risks. The values along this axis form planes of points which inform us about the quantity of the risk.

In risk measurement a vector method is suggested for defining and determining criticalities and safety analytically [2]. The influence of the elementary and phase conversions is considered, as well as the influence of the risks in cause-effect relationships. The method is based on four definitions: 1) Criticalities are a combination of risks of dangerous phenomena, dangerous activities and dangerous effects arising in time; 2) The indicator criticality is a system of indicator risks arising in time, while the componential criticality arises from componential risks, respectively; 3) The differential criticality is a totality of arising in temporal function risks for separate appearance of dangerous phenomena, of dangerous activities and of dangerous effects; 4) The integral criticality is a combination of appearing together componential risks of dangerous phenomena, dangerous activities and dangerous effects. The criticalities can be presented in a diagram. Areas of points are formed for each value of the components $R_{ind_{Fen}}$, $R_{ind_{Act}}$, $R_{ind_{Eff}}$ in the plane R_{Tind} – R_{ind}. Each one of these areas depicts the indicator differential criticalities $Gsit_{Fen}$, $Gsit_{Act}$, $Gsit_{Eff}$. The size of the vectors to the centres Cdc_{Fen}, Cdc_{Act}, Cdc_{Eff} of the areas of points determines the differential criticalities.

Each point of the mentioned areas has a corresponding point in the dimension of the componential differential risks. They form the planes $Gsat_{Fen}$, $Gsat_{Act}$, $Gsat_{Eff}$. Each plane is represented by the centres Cic_{Fen}, Cic_{Act}, Cic_{Eff}. The vectors are determinants of the componential differential criticalities. The integral criticality G_{Integ} is defined by the size of the set of componential risks $Gsat_{Fen}$, $Gsat_{Act}$, $Gsat_{Eff}$.

The ecological insecurity is equal to the criticalities. The sum of the ecological safety and the ecological insecurity is 1 as they are alternatives. This regularity determines the ecological safety.

CONCLUSIONS

This study suggests and presents a procedure for measuring the risk which reflects precisely and thoroughly the threats to the environment caused by economic activities.

The paper explains the logics behind the risk measurement.

It works out the order and content of the measurement procedure and shows arguments for the operations, the measurement values and the measurement units.

The article presents the way for defining the numerical values of the risk and through it we define the criticalities and the ecological safety.

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