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Algorithmization of Ecologo-Economic Risk-Management in Urban Areas

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Abstract

The article is devoted to the development of scientific approach to the problem of rationalizing the mutual influence of natural and economic relations elements which exist within the boundaries of urban (city) environment. The phenomenon of ecological and economic interaction is of particular relevance in terms of sustainable development concept, which determines the necessity of present needs satisfaction without any trouble for the future generations. The level of risk is the main quantitative indicator of the sustainable development degree. The author makes an effort in analysis and management of ecological-economic risk algorithmization. To this aim, the concept of ecological and economic risk is clarified, there is shown the general classification, the standard approach to quantitative risk assessment is considered, the features of analysis and evaluation of the risk level are studied. There is a general algorithm for management of ecological and economic risk, that consists of a number of analysis and assessments. The first block includes the steps of risk identification, or the definition of events that might cause ecological and economic damage of the probability of adverse events, or the possibility of determining the risk situation for a certain period, determining the structure of possible damage, or analysis of the results of adverse events, identifying the distribution system of damage, or the analysis of patterns of spread of the probability of damage to the same objects with similar adverse conditions, risk assessment, or, determination of quantitative characteristics (integral estimates) of risk measure. The second block includes the steps of evaluating the effectiveness of the risk response methods to avoid it, to reduce or transfer risks; the choice of the most appropriate ways to influence the risk, or, the definition of a list of specific control measures, monitoring progress in the implementation of risk control, or monitoring the state of the environment and the potential sources of danger. In conclusion, according to the results of the assessment of environmental and economic risk, it is given an example of management analysis of the territory of Rostov-on-Don.

Keywords: analysis, risk management, ecological and economic risk, urban areas, management algorithm

1. Introduction

The concept of "risk" is usually interpreted in scientific literature as concept of "danger", which means there is an opportunity for negative impact being able to cause any damage or injury (Domgjoni, 2014). The concept of damage is usually associated with deterioration, breach of normal operation, or destruction of object. In this context, risk determines the quantitative measure of danger, or, its probability (Wang et al., 2014).

In general case environmental and economic risks are defined as economic losses risks of different level management objects as the result of deterioration of natural-built environment (Veeravatnanond et al., 2012), which might have a slow (evolutionary) or rapid (catastrophic) character (Verdonck, 2003). Almost all the levels of urbanization - place of human life, land of enterprises and organizations, territorial-production and ecological complexes, regions, states, world community are under conditions of ecological and economic risks (Borden).

2. Method

A regular deviation classification of ecological environmental quality from the standard indicators is impractical and difficult because of big nature differences and ambiguous consequences of adverse events multiplicity (Englehardt, 1998). There is only a generalized grouping of environmental violations by impact type allowed (Meng et al., 2011):

– physical: radioactive, heat, noise, vibration, ionizing;
– chemical: carbon-hydrocarbons, synthetic substances (would-tum chemistry, plastics, pesticides), derivatives of sulfur, nitrogen, heavy metals, fluorine compounds, aerosols;
– biological: bacteria and viruses, breach of biological balance;
– mechanical: dumps, destruction of vegetation, disturbance of landscapes and scenery.

"Damage scale" is a term used for economical characteristics of adverse events probability. Quantifying the risk, this approach allows us to apply the tools of economic and mathematical methods and to interpret the magnitude of the risk as a damage expectation defined by a set of possible adverse events (Liu et al., 2011).

Therefore, the indicator of average risk should be used to formalize the interpretation of quantitative risk measures, which takes both characteristics of adverse event - the probability of occurrence and magnitude of the caused damage into account (Anopchenko & Murzin, 2014):

$$R = \sum_{i=1}^{n} P_i X_i , \quad (1)$$

where R – is the quantitative measure of risk expressed in terms of damage; P_i – is the probability of damage due to adverse events; X_i – is the damage value, expressed in value terms; n – is the number of possible variants of adverse events.

3. Results

Analysis of ecological and economic risk as an element of management is an ordered sequence of researching steps which follow to identifying reliable and objective characteristics of the possible damage (Murzin, 2012), as well as its cutoff activities (Figure 1).

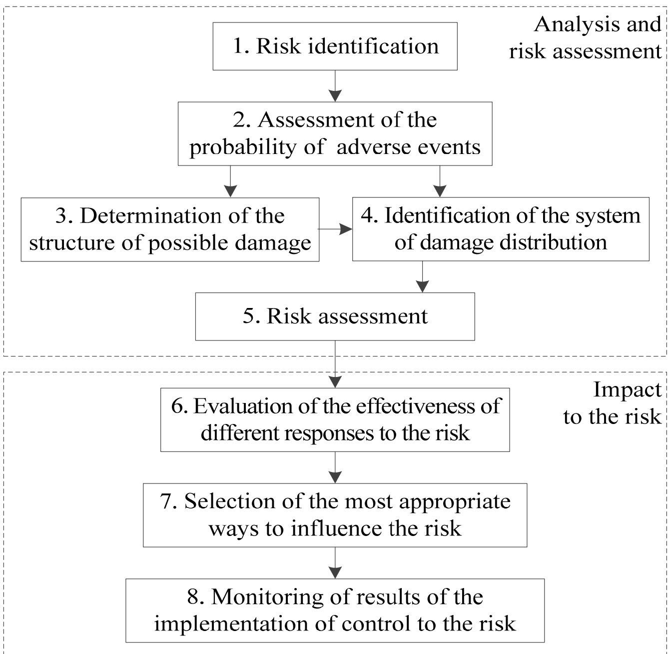


Figure 1. The control algorithm of ecological and economic risks

The structure of the stages of ecological and economic risk management includes two blocks. The aim of the block of stages of analysis and risk assessment is to determine the quantitative indicators which are conformed to different scenarios of adverse events. The block of stages of influence on the risk focuses on identification of specific measures that can cutoff the amount of potential damage and monitor their effects.

1. The main purpose of stage of risk identification is to define adverse events that might be cause of worse environment qualities and cause of economic damage to a territorial subject.

An important purpose of this stage along with the definition of the list of possible events is to watch the cause-and-effect relationships of consequences of such events (Gentile et al., 2001). It is supposed to make a reasonable conclusion about the possibility of real damage at the stage of risk identification. The damage from adverse events might have mediated forms and manifest itself after a certain period of time.

Risk identification can be based on formal or informal approaches using objective or subjective information. Subjectivism reflects the experience and knowledge of the experts, objective data includes factual information on the consequences in past, results of analytical studies of the causes of damage, natural experiments.

2. The stage of evaluation of the probability of adverse events allows to assess the risk situation for a certain period of time. There are three main groups of methods of estimating the probability of adverse events (Schoppe et al., 2014): statistical methods – which are based on analysis of the statistics of negative events on similar sites of the territory in past; analytical methods – which are based on the study of causal relationships of territorial and production system and allow us to estimate the probability of an unfavorable situation, formed by the combination of a sequence of elementary events; expert methods -they involve the assessment of the probability of events based on the results of a survey of the experts.

3. The stage of determining the structure of possible damage means to study the results of the manifestation of adverse events. Feature display of ecological and economic risks is the possibility of indirect consequences of adverse events, their indirect influence on objects through environmental degradation. The structure of the potential damage can be presented in bulk or value. Natural damage is measured by quantitative characteristics that reflect the physical deterioration or loss of the object's properties:

$$X_{экол} = \prod \left(\sum_{i=1}^{n} \frac{Y_i}{H_i} + 1 \right)^{B_i} - 1, \tag{2}$$

where Y_i - is the load level of components of area (air, water, soil) by the physical pollutants (mg / m^3), the wave fields: noise (dBA), vibration (dBA), electromagnetic (V/m) and ionizing radiation (mR/hr); H_i - is the standard level of load capacity of corresponding figure; B_i - weighting coefficient of the corresponding component of the environment.

$$X_{econ} = \frac{\sum Y_i}{B}, \tag{3}$$

where Y_i - is the economic damage of pollution of the corresponding component of the environment; B - is the budget of environmental activities of the territory (taxes, environmental payments, and so on).

4. The stage of detection of system of the damage distribution provides a definition of spread of the probability of damage to the objects of the same type with similar adverse events regarding to their strength (Thongsri, 2005). It is not possible to predict reliably the amount of potential damage in each case (Murzin, 2012), therefore, identified at this stage patterns are considered as provisional and are likely to be expressed in the interval (Table 2).

Table 1. The scale of expert estimates of the probability of risk

Quality level	P_i
Critical	0,00 - 0,19
Dangerous	0,20 - 0,36
Allowable	0,37 - 0,62
Acceptable	0,63 - 0,79
Background	0,80 - 1,00

Note. P_i – is the probability of damage due to adverse events.

It is common to use model laws of distribution of damages (exponential, normal, lognormal, and so on) in studies of ecological and economic risks, which are usually with some degree of certainty reflect empirical frequency of dimensions of incurred losses in similar, past situations. This is due to the fact that for each possible case formulation is impractical in practice due to high labor costs.

5. The main aim of the stage of determining the quantitative characteristics of risk measures is the formation of its quantitative indicators (integral values), which can be used for the development of administrative decisions.

The expectation damages can serve as quantitative tools to determine the measure of risk (Formula 1), which reflects the information on the average loss for the analyzed period, objectively incurred in the chosen strategy of behavior. The protect strategy from the effects of adverse situations is selected on the basis of the maximum acceptable value and the allowable probability of damage occurrence, which is taken as a minimum possibility of damages. So, the allowable level of annual damage probability in case of an accident in an industrial plant is determined by the size of 10^{-5}-10^{-6} (Shoygu, 1999).

In some areas of the analysis of ecological and economic risks the assessment is not compared to a value form of damage, but is based on the need for events matching which take place in the adjacent areas of life. This way, indicators of risk of environmental pollution can be formed being based on the likelihood of diseases that appear with a constant presence in the area of carcinogenicity or they can be expressed in the form of a general index of sickness rate (Gilmundinov et al., 2013).

Maximum acceptable damage is a sign for measures to protect the environment from polluting effects. The magnitude of damage below a designated level is taken as the natural level of risk, and its reduction does not make any noticeable effect because of the excess of costs of the protective measures comparing to the magnitude of potential losses.

6. The stage of assess of the effectiveness and selection of methods to influence the risk involves the creation of possible actions list, which is divided into several groups (Sereda, 2013): avoiding risks; reducing the probability of an adverse event; reducing caused damage; transfer of risk. Methods of compensation are included in a separate group.

Realizing each of the methods we need to determine the costs which are different in their level. The problem of risk management is to identify and implement the optimal set of methods being able to reduce the total costs caused by environmental pollution, or to obtain the maximum benefit. In general, total costs are defined as the amount of losses caused by adverse events and costs associated with risk.

The goal of management is to reduce the total cost regarding to pure risk (possibility of damage), and is the profit regarding to speculative risk (possibility of benefits). In this case, we should make difference between management that directly implies a decrease in the amount of risk (net risk), and management that has conditions for the existence of risk (speculative risk).

Choosing the management methods to control ecological and economic risks we must take into account economic efficiency as well as the constraints of interaction between the economy and nature, as well as the need for steady environment, and the reasonable protection of the individual against the adverse effects and so on (Lai et al., 2014). Therefore, the policy of risk management should be carried out within the allowable risks for ecosystem. In other words, no cost-optimal solutions might be accepted if they bring the anthropogenic impact on the environment, bigger than its capacity or if there is any risk for human life, even if it makes tangible benefit for society.

The need for taking into account all the restrictions is taken as a base in the structure of risk, which is generally divided into zones (Figure 2):

– Excessive risk (ER), which includes the area of critical loss (CL), and excess profits (EP);
– Critical risk (CR), which includes the area of allowable loss (AL), and wanted profit (WP);
– Permissible risk (PR), which includes the area of the estimated loss (EL) and calculated profit (CP);
– Acceptable risk (AR), which characterizes normal operating.

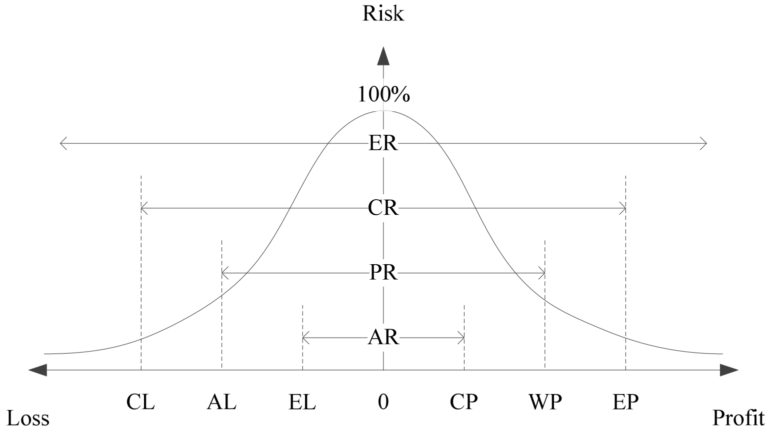


Figure 2. Ecological and economic risk zones

Critical risk zone includes the values of risk which are much greater than its allowable level. There is no practical activity within the boundaries of this zone if protective measures are not able to reduce the level of possible risks to their acceptable values. This zone defines the boundaries of sustainability of the ecosystem in environmental field, in other words, it defines the amount of anthropogenic influence on the environment in which the natural system is able to maintain its basic properties and to assimilate the adverse effects results.

Table 2. Risk indicators on the territory of Rostov-on-Don

Area	Functioning area	R_{ecol}	R_{econ}
Oktyabrsky	*Industrial* Voenved	0,208	0,335
	Living Voenved	0,194	0,203
	Industrial Kamenka	0,191	0,235
	Living Sheboldaeva / Lenin	0,206	0,335
	Living Budeonovsk / Mechnikov	0,177	0,252
	Parkland	0,297	0,205
Voroshilovsky	*Industrial* Autostation SJM	0,217	0,542
	Living SJM	0,188	0,349
	Park SKA	0,344	0,242
	Industrial VertolCity	0,152	0,474
	Living Lenina / Nagibina	0,160	0,160
Pervomaysky	*Living* Chkalova	0,319	0,440
	Industrial Selmash	0,102	0,980
	Park Ostrovsky	0358	0,110
	Living Selmash	0,050	0,070
	Living Ordjonikidze	0,139	0,274
	Recreational Ordjonikidze	0,425	0,155
	Industrial Airport	0,184	0,779
Proletarsky	*Industrial* Empils	0,193	0,336
	Park Teatralny	0,661	0,129
	Living Nahichev Sovetskaya	0,176	0,213
	Recreational Aleksandrova	0,303	0,139
	Living Verhn Aleksandrovka	0,062	0,074
	Living Nijn Aleksandrovka	0,083	0,074
	Industrial Krasny Aksay	0,228	0,350
	Industrial Port	0,183	0,360
Kirovsky	*Industrial* Sudostroitelny	0,182	0,329
	Living Teatraln Bogatyanovsk	0,025	0,071
	Living Kirovsky Voroshilovsk	0,105	0,071
	Industrial ATP Tekucheva	0,166	0,249
	Recreational Dinamo Stadium	0,164	0,071
Leninsky	*Living* Beregovaya / Sadovaya	0,089	0,096
	Living Krasnoarmeiskaya	0,101	0,096
	Living Mechnikova / Nansena	0,137	0,096
	Industrial Railway Station Area	0,102	0,297
	Industrial Kirpichny zavod	0,151	0,128
Zheleznodorojny	*Living* Verhnegnilovskoy	0,071	0,106
	Living Nijnegnilovskoy	0,170	0,206
	Living Krasny gorod	0,290	0,321
	Industrial Railway Station Square	0,103	0,450
	Recreational Botanichesky sad	0,301	0,096
Sovetsky	*Industrial* Peskova GPZ	0,174	0,371
	Living Kommunistichesky	0,235	0,301
	Recreational Sady	0,470	0,308
	Living Zorge	0,249	0,298
	Living Zmievka	0,390	0,336
	Industrial North-West Industrial Area	0,086	0,200

Note. R_{ecol} – ecological risk assessment; R_{econ} – economic risk assessment.

The zone of permissible risk includes risk values with levels not higher than typical. Risk management activities within the boundaries of the zone bring a significant effect such as total amount of cost savings and fall of the social risk consequences (Marmot, 1998).

Acceptable risk zone includes values of risk indicators with the presence at the level of the background values. The risk reduction becomes uneconomical within the boundaries of this zone because preventive measures do not make much effect, or, there is a possibility for normal functioning (of life) and losses due to the complex of forming factors influence.

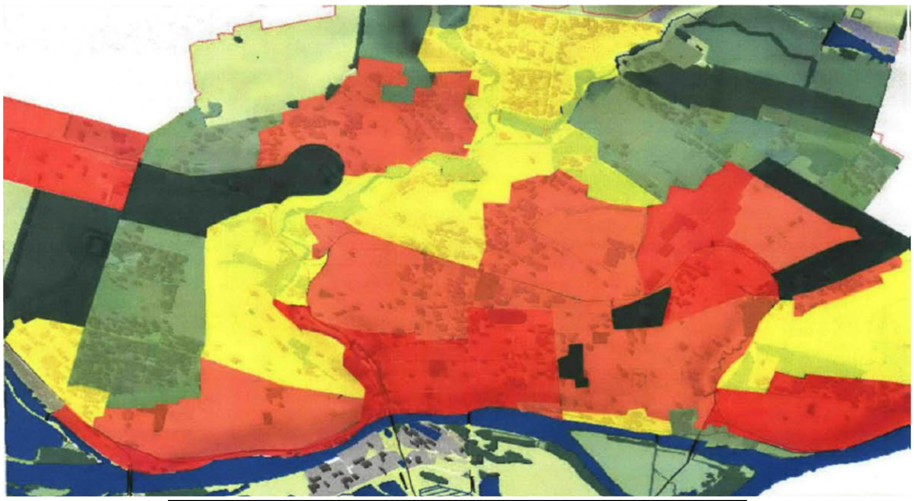
7. Stage of the control of results of the risk management process is carried out during environmental monitoring, hazards examination, construct projects, licensing of a certain types of activities, and inspections.

Monitoring is a regular performance of the known program of observations of abiotic and biotic environment, as well as control of its anthropogenic influence. Usually monitoring objects are natural areas, Geosystems, man-made sources.

It is possible to assess the quality of the environment with monitoring, possible to determine the degree of ecological environment and biological objects interference, to set the boundaries for environmental degradation and sources of anthropogenic impact. This way it is information base formed that is needed to evaluate characteristics and sources of the risk.

Environmental monitoring includes measuring of pollution concentrations, strength and duration of physical impacts on the environment, and monitoring of living organisms –which are characterized as biological indicators that respond to environmental degradation, by changing its vital functions or accumulating pollutants. Measuring of pollution concentrations involves evaluating the dose pollutant and its impact on the environment quality. Overall assessment of the environment quality is carried out by the compare results of observation and established standards. If there is a quality deterioration it is a sign of risk emergence.

The variation of operation modes of facilities and the strength of their impact on the environment is involved in the control process of the anthropogenic impact sources. This control is based on comparing the characteristics of current and regulatory work regimes, and real and regulatory limits facilities on the environment. Any deviations from the standard are considered as the risk occurrence (Korableva & Kalimullina, 2014).



Characteristics	Color
Zone of critical risk	Red
Zone of danger risk	Pink
Zone of permissible risk	Orange
Zone of acceptable risk	Yellow
Zone of background risk	Green

Figure 3. Map of the risk assessment territory

Ecological examination is conducted in order to establish the conformity of business environmental standards and regulations. The examination is conducted at the stage of deciding on the possible implementation of economic activity in an ecosystem (Kareiva, 2001). Identified during the environmental review violations of environmental standards and regulations are the basis to classify the project as the category of risk or reject it.

Table 2 represents the results of the process of analysis and assessment of environmental and economic risks by the algorithm according to the current situation in the urbanized areas of the city of Rostov-on-Don.

The results might also be represented in the cartographic form (Figure 3), which helps to visualize the need for environmental protection measures in the zones of the city.

4. Discussion

According to the results of risk assessment, there might be offered a set of control measures that could help to reduce the probability of the adverse impact and economic damage in the city (Table 3).

Table 3. The areas of control action of the ecological and economic risk reduction in areas of Rostov-on-Don

Indicator	Variable parameters	Control actions
R_{ecol}	The concentration of dust, carbon monoxide, nitrogen dioxide, nitric oxide, formaldehyde, phenol, benz pyrene, fluoride and hydrogen chloride	To restrict the quantity of transport in central part of the city, parking organization, to increase the intensity and comfort of public passenger transport
	The concentration of the sulfur oxide, phenol, hydrogen sulphide, ammonia, lead, formaldehyde, dust, and carbon monoxide	to remove of production facilities with environmental protection areas, to form recreational areas
	The concentration of sulfates, nitrites, compounds of copper, zinc, iron, oil, organic compounds	to relocate of production and industrial facilities; to reconstruct and modernize the sewerage system
	The area of polluted land, illegal dumps	to purification landfill foci and prevention of illegal waste dumping
R_{econ}	The land rent, real estate, taxes, deductions in the local budget	Priority of research and production, business, commercial enterprises, service facilities and commercial, business purposes, administrative centers; the transfer of production facilities from environmental protection areas to the outskirts of the city and beyond, the formation of the recreational areas that are profitable to the city budget

5. Conclusions

Thus, this is the most generalized algorithm, which describes the management of ecological and economic risk, that appears in the natural and economic relations in urban areas. This algorithm allows to determine the characteristics of the particular ecological and economic risk and to develop the most effective way to control the impact of sustainable development of urban areas.

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