ENVIRONMENTAL PROBLEMS

Vol. 2, No. 1, 2017

THE METHODOLOGY OF ENVIRONMENTAL IMPACTS ASSESSMENT OF ENVIRONMENTALLY HAZARDOUS FACILITIES

Yaroslav Adamenko

Ivano-Frankivsk National Technical University of Oil and Gas,
15, S. Karpatska str., Ivano-Frankivsk, 76019, Ukraine, yarad@inbox.ru

Received: 22.11.2016

Abstract. The article deals with the methodology of environmental impacts assessment of environmentally hazardous facilities and activities. The stages of evaluation of environmental impacts are proved. The algorithm and technology of decision-making in the system of environmental impact assessments based on a multi-criteria utility theory are proposed.

Key words: environmental impact assessment, alternative, environmental impacts, utility theory, decision-making.

Introduction

The adoption of environmental laws and procedures for environmental impact assessments (EIA) in different countries has accelerated the development or modification of many technologies for environmental impact assessment [1, 2, 3]. However, the impact assessment still remains largely a subjective process. Although the evaluation of existing environmental conditions can be carried out with reasonably high degree of accuracy and certainty, the impact forecasting will continue up to the gains from new methodologies and improvements in existing technologies.

When developing a common approach to forecasting and environmental impact assessment, there are some fundamental questions to be asked at the beginning of the planning process. These issues should disclose:

– availability of sufficient effective mathematical models to predict and maintain quantitative component of environmental impact assessment;

– quantitative threshold (i.e., standard or general criteria applicable) that can be used to distinguish high levels of environmental impacts from all the possible ones;

– availability of quantitative and statistical methodology suitable for an objective description of impact levels or subjective application at one or more evaluation stages;

– availability of related evaluation methods, carried out for similar activities.

Formulation of the problem

Environmental impact assessment (EIA) while considering the proposed activities are generally carried out as follows [4]:

1. Analysis of the environment:

– collection and analysis of the existing information within the area of the proposed activity impact;

– direct methods of studying the environmental factors within the area of the proposed activity impact;

– the study of the environmental factors on the issues of scoping procedures.

2. Environmental assessment:

– existing – within the area of the proposed activity impact;

– on the proposed alternatives.

3. Comparison of the environmental factors:

– with the existing condition;

– between the alternatives.

4. Selection of the best alternative in terms of maximum environmental protection.

Ideal circumstances for evaluation will be where a substantial database is available, specific for the place or territory, which is being estimated, where there are well-tested prediction models using these data categories, where there is common agreement among the professionals on the level of environmental impact to be considered "significant", where the need for subjective evaluation is minimal or absent, and where other documentation on similar assessments is available. But it would be incredible if there were lots of such situations when these ideal conditions do exist, and most of EA require significant contribution of professional opinion. In such situations, the study of cases in which the situations can be compared, add understanding of the scope and extent of the impact.

Information on the existing conditions and potential environmental impact, which is collected during the EA, ultimately leads to the definition of preferable alternatives, which can achieve the objectives of the proposed activity, holding the undesirable environmental impact at almost minimal level. That's why the definition of such alternatives must be rigorous and objective, as well as the documentation on conditions and influence.

In Ukraine at this stage of the EIA (and therefore in a similar section of the EIA) a comprehensive assessment of the projected activities impacts on the environment is carried out on the basis of partial assessment referred to in the previous sections, under conditions of the implementation of measures on ensuring environmental regulation. That is, for the existing approach to EIA in Ukraine:

– the degree of environmental risk design activity is determined;

– the optimality as for the environmental position of the adopted complex of design solutions is justified;

– the list and description of residual impacts is presented;

– environmental admissibility of residual impacts during the construction and operation of the projected activity is justified.

In the world, at this stage of the EIA, relative merits of several alternatives are usually considered in three promising areas:

1) engineering capabilities and requirements;
2) economic opportunities of implementation;
3) ecological safety.

Professionally made decision is based on correct understanding of the situation, structure and complex (system) nature of its components, taking into account key factors and trends, identifying effective ways to achieve the goals.

Basic material

Analyzing the problem of decision-making in the system of EA and environmental expertise, it was found that making decisions is based on the total information on the situation, its careful analysis and assessment, and herewith the general role belongs to the definition of the objectives of the proposed action. Only after its determining it is possible to define the factors, mechanisms, laws and resources that affect the development of the situation.

For the purpose of the sequence of understanding of expert decision-making technology for EIA, the author proposed a block diagram of the procedure (Fig. 1). This technology is based on a multi utility theory (MUT) [5], based on a single mathematical apparatus with the definition of utility function depending on the preferences of experts, and the obtained results allow to assess any alternatives, including those that may arise in the their future consideration. The proposed methodology is described by the algorithm (Fig. 2) and mathematical tools that are given below. These general approaches can be used both for primary generation and final discussion of the alternatives. But already at determining the alternatives, which should be given preference, discrimination means for comparing several alternatives suitable for the decision-making procedure ought to be used as much as possible [6].

The decision on the introduction of technologically safe investment is made considering engineering opportunities, economic feasibility and environmental safety in view of the proposed alternatives. To solve this problem, it is proposed to use MUT with calculation of individual utility functions for each alternative and criteria as follows:

$$P = U_{Eng.}^{A_n}(C_i^{Eng.}) + U_{Ekon.}^{A_n}(C_j^{Ekon.}) + \\ + U_{Ekol.}^{A_n}(C_k^{Ekol.}), \qquad (1)$$

where, P – decision-making; $U_{Eng.}^{A_n}\left(C_i^{Eng.}\right)$ – utility function of the ***n***-th alternatives by the ***i***-s criteria of engineering capabilities and requirements as to the proposed activity; $U_{Ekon.}^{A_n}\left(C_{\mathrm{j}}^{Ekon.}\right)$ – utility function of the ***n***-th alternatives by the ***j***-s criteria of economic opportunity and feasibility as to the proposed activity; $U_{Ekol.}^{A_n}(C_k^{Ekol.})$ – utility function of the ***n***-th alternatives by the ***k***-s criteria of environmental safety as to the proposed activity.

Engineering opportunities and requirements are quantitatively calculated in terms of the requirements for the enterprise; estimated costs for these essential characteristics; installation costs of equipment and its maintenance; estimates for the cost of commercial and engineering structures in place in the mode of new equipment designing. The structure of these assessments is well worked in the industrial and commercial sectors in almost every country.

Similarly, economic factors of choosing an alternative activity can be determined in the currency that is well understood by all stakeholders and must be determined for each real alternative. Evaluation of economic costs, economic benefits, changes in tax structures, infrastructure and power requirements, and operational capabilities that form the basis of this assessment, are well understood and use generally accepted technology.

Fig. 1. Flowchart ot expert technology of decision-making for EIA procedure

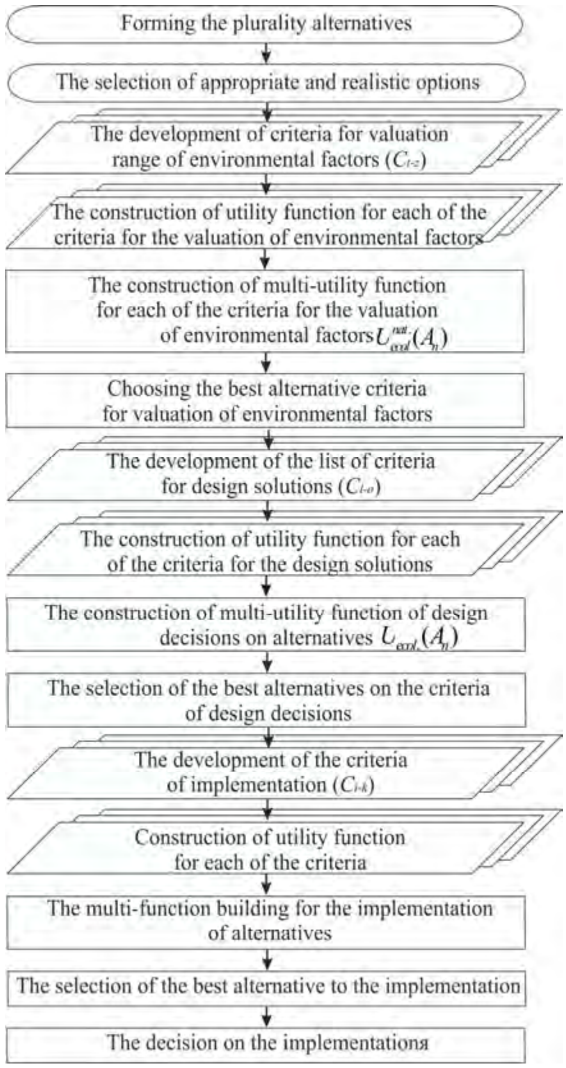

Fig. 2. Decision-making algorithm in the EIA system

The environmental safety of any alternative is the most difficult aspect in choosing the alternative regarding its quantitative evaluation. You can calculate the risks and gains of the proposed activities, but these forecasts assess environmental changes and can only sometimes be expressed in economic terms. Generally, all stakeholders understand the value of the environment: expanses of local vegetation; wetlands, coastal strips, diverse wildlife communities etc. However, it is difficult to express the balance of environmental performance losses or the impact on them in the same units as technical needs or economic gains.

To determine the utility function of ecological safety, it is necessary to establish the criteria of project solutions, which are formed by regional, local and regulatory parameters (or criteria) of the proposed activities. The function of ecological security is based on MUT with calculation of individual utility functions for each alternative and criteria according to the formula proposed by the author:

$$U_{Ecol.}(A_n) = \sum U_{reg.}(C_l^{reg.}) + \sum U_{loc.}(C_m^{loc.}) + \sum U_{ter.}(C_o^{ter.}), \quad (2)$$

where, $U_{Ecol.}(A_n)$ – utility function of ecological safety of the ***n-th*** alternative by the criteria of design solutions on the proposed activities; $U_{reg.}(C_l^{reg.})$ – utility function by the ***l***-s criteria of the enlarged regional optimization of project solutions; $U_{loc.}(C_m^{loc.})$ – utility function by the ***m*** -s criteria of project solutions optimization at the local level; $U_{ter.}(C_o^{ter.})$ – utility function by ***the o***-s criteria of city-building, sanitary and environmental constraints within the area of the proposed activity influence.

Particular attention should be paid to the simultaneous application of the optimizational non-threshold and restrictive threshold criteria. The results of the optimization are constantly checked for compliance with applicable rules of restrictions. To select alternatives and decision making as a part of environmental assessment, valid standardized and non-normable criteria are applied for natural, technological and social environments.

Each of the aforementioned utility functions (2) is calculated by the criteria of rationing the effects on the natural, social and technological environments. In general, it is proposed to establish the function of environment rationing in the implementation of the proposed activity, based on MUT with calculation of individual utility functions for each alternative and criteria as follows:

$$U_{ekol.}^{nat.}(A_n) = \sum U_{nat.envir.}(C_p^{nat.envir.}) + \sum U_{tech.envir.}(C_r^{tech.envir.}) + \sum U_{soc.envir.}(C_s^{soc.envir.}), \quad (3)$$

where, $U_{ecol}^{nat.}(A_n)$ – utility function of ecological safety of the ***n***-th alternative by the criteria of the environment rationing; $U_{nat.envir.}(C_p^{nat.envir.})$ – the utility function by the ***p***-s environment criteria; $U_{tech.envir.}(C_r^{tech.envir.})$ – utility function of ecological safety by the ***r***-s industrial environment criteria; $U_{soc.envir.}(C_s^{soc.envir.})$ – utility function by the ***s***-s social environment criteria.

In turn, each of the utility functions (3) takes into account all the factors of a database of environmental information developed by the author for each component of the environment:

$$U_{nat.envir.}^{nat}(A_n) = \sum U_{geol.}(C_t^{geol.}) + \sum U_{atm.}(C_v^{atm.}) + \sum U_{hydr.}(C_w^{hydr.}) + \sum U_{soil.}(C_x^{soil.}) + \sum U_{bio.}(C_y^{bio.}), \quad (4)$$

$$U_{tech.envir.}^{nat.}(A_n) = \sum U_{tech.envir.}(C_z^{tech.envir.}), \quad (5)$$

$$U_{soc.envir.}^{nat.}(A_n) = \sum U_{soc.envir.}(C_q^{soc.envir.}), \quad (6)$$

where, $U_{nat.envir.}^{nat}(A_n)$ – utility function of the ***n***-th alternative by the criteria of environment rationing; $U_{tech.envir.}^{nat.}(A_n)$ – utility function of the ***n***-th alternative by the criteria of man-made environment rationing; $U_{soc.envir.}^{nat.}(A_n)$ – utility function of the ***n***-th alternative by the criteria of social environment rationing; $U_{geol.}(C_t^{geol.})$ – utility function by the ***t***-s criteria of geological environment; $U_{atm.}(C_v^{atm.})$ – utility function by the ***v***-s criteria of atmospheric environment; $U_{hydr.}(C_w^{hydr.})$ – utility function by the ***w***-s criteria of aquatic environment; $U_{soil.}(C_x^{soil.})$ – utility function by the ***x***-s criteria of soil; $U_{bio.}(C_y^{bio.})$ – utility function by the ***y***-s criteria of biosphere (vegetation, fauna, protected areas); $U_{tech.envir.}(C_z^{tech.envir.})$ – utility function by ***z***-s criteria of man-made environment; $U_{soc.envir.}(C_q^{soc.envir.})$ – utility function by ***q***-s criteria of social environment.

Utility function of alternatives selection for the environment is described by the following criteria:

– rational use of natural resources;

– the maximum permissible load on quantitative estimates of negative impacts on area unit;

– ecological capacity of the territory by the ability of self-cleaning or self-healing of natural complex under the negative influence;

– energy assessment of the environment quality;

– biological productivity of biogeocoenose with the rate equal to the intensity of solar radiation at a latitude of the area;

– minimizing of damage to the environment for the planned activities;

– ecological limits according to environmental regulations ($MPL_{s.d.}$, $MPL_{m.r.}$ and others) of natural-territorial complexes, including vegetation;

– synergy (additivity, potentiation, antagonism);

– comparison with natural background and its variations;

– sustainability – stability of basic characteristics and parameters of the ecosystem;

– limiting factors (tolerance) – approximation of environmental factors to the upper or lower limit of tolerance, including biogeocenotic metabolism and energy.

Utility function of alternatives selection for man-made environment is described by the following factors:

– the economic feasibility of the proposed activity;

– "benefit-harm" balance criterion;

– expanded ecological and economic criterion (in monetary terms);

– planning ecological and economic criterion (in monetary terms);

– criterion of the cost of environmental measures to ensure normalization of the environment in the zone of the objects impact;

– criterion of technical implementation of the proposed activities;

– criterion of the opportunity to reduce emissions (g/s, t/year) discharges (mg/dm^3, t/year) and the volume of solid waste (t/year) and corresponding reduction of air pollution (mg/m^3), water (mg/dm^3) and soil (mg/kg).

Utility function of alternatives selection for social environment is described by the following criteria:

– maximization of population welfare;

– minimization of the negative impact on the population;

– sanitary restrictions ($MPL_{s.d.}$, $MPL_{m.r.}$ and others);

– social-economical indicators of changes in conditions of vital activities of the population;

– public opinion;

– planning of environmental and economic needs and compensations (in monetary terms) considering negative effects on human health.

Conclusions

The proposed methodology of decision-making on the introduction of environmentally sound activity is built on a single flexible MUT mathematical theory that allows justifying specific utility function. The obtained functions make it possible to assess any alternatives by the unspecified number of criteria of their impact on the environment, depending on the experts' preferences.

The decision on the choice of the alternatives is a critical point in which the organization of the complex of afferent impulses, able to give a definite effect, takes place. Under any circumstances it is necessary to choose one of the proposed alternatives and reasonably exclude all the others. The decision-making transfers a systemic process – afferent synthesis – into another system process – action program. This process is a transition point, after which all combinations acquire executive character.

The decision-making process is central at all levels of information processing by individuals, groups and "man-machine" systems. This complex task involves different aspects: physiological, cybernetic and others. There are two main stages in the process of decision making: information preparation of the solutions and decision-making itself.

Based on the own experience, the most appropriate for EIA is the use of methods of building such models as: multi-criteria utility theory, approach of analytic hierarchy, ranking of multi-criteria alternatives and decision making under uncertainty [7].

The proposed methodology of decision making intended primarily to compare alternatives and choose the best of them. Quite often, the criteria by which alternatives are evaluated, are contradictory, they use different methods and scale of assessments.

That is the main problem in dealing with multi-criteria tasks. The best option to solve such problem will be the one, which achieves the prevailing compromise between the criteria in terms of experts or people who make decisions. With a great number of alternatives and criteria, experts it is rather difficult to orientate and make the best decision.

References

[1] Buks I., Fomin S.: Ekologicheskaya ekspertiza i ocenka vozdeistviya na okrujayuschuyu sredu (OVOS). Moskva, MNEPU, 1999, 254.

[2] Adamenko O.: Mistse i rol OVNS v sistemi ekologichnoyi bezpeki teritoriyi abo ob'ektu. Zbirnik materialiv: Normativni ta praktichni aspekti vikonannya otsinki vplivu na navkolishne seredovishche, Kiyiv, Veselka, 2002, 62–64.

[3] Lee N., Colley R., Bonde J. Reviewing the Quality of Environmental Statements and Environmental Appraisals. University of Manchester. UK, 1999, 72.

[4] Kalinovskiy S.: Otsinka vplivu i ekologichna ekspertiza sogodni i zavtra. Zbirnik materialiv: Normativni ta praktichni aspekti vikonannya otsinki vplivu na navkolishne seredovishche, Kiyiv, Veselka, 2002, 8-19.

[5] Makarov I.: Teoriya vybora i prinyatiya resheniy. – Moskva, Nauka, 1987, 421.

[6] Ya. Adamenko, M. Coman The Methodology of Decision-Making within Procedures of Environmental Impact Assessments / Wulfenia Journal (ISSN:1561-882X) – Klagenfurt, Austria. – Vol. 23, No. 6. – Jun. 2016. – 377–384 p.

[7] Adamenko Ya.: Otsinka vpliviv tehnogenno nebezpechnih ob'ektiv na navkolishne seredovishche: naukovo-teoretichni osnovi, praktichna realizatsiya. Disertacia doktora tehnichykh nauk: 21.06.01, Ivano-Frankivsk, 2006, 425.