Serhiy Kozmenko (Ukraine)

Economic evaluation of the consequences of disasters

Abstract

The article analyzes the basic definitions of emergencies, disasters, elements and technological accidents. It gives the characteristics of the main consequences of disasters and offers an algorithm for the economic evaluation of these effects.

Keywords: disaster, technological accident, catastrophe, direct and indirect economic damage.
JEL Classification: Q51, Q54.

Introduction

The whole history of the Earth is rife with different kinds of cataclysms, catastrophes, conflicts, crises, etc. With the passage of time and development of the humankind the purely natural phenomena at first acquired an anthropological colouring (disturbance of the infrastructure created by humans), then the objects of human activity began to violate the natural environment. At present, almost all environmental phenomena have acquired the natural and anthropological character.

In the recent years emergencies caused by natural calamities or man-made accidents have become very frequent, and their consequences – very tangible for various levels of the economic activity.

Nevertheless, the issues of scientific and methodical provision for the preventive and localizing measures do not receive much attention. We encounter certain problems already on the phase of the study of the cognitive apparatus.

1. Determination of the catastrophes

Catastrophe (natural calamity or man-made accident) is a large-scale, relatively accidental occurrence, which is a serious threat with unpredictable consequences for socio-economic and environmental systems.

Under natural calamities we understand natural phenomena or processes, which are practically not controlled by man and which are characterized by uncertainty in time and consequences. In case, when people and their property are directly affected, the natural phenomena are defined as natural disasters.

Major technological accident is an event (emission of harmful substances, fire, explosion), which occur as a result of uncontrolled changes during the exploitation of technical objects leading to serious threats (directly or with delayed effects) for the health of people and the environment.

2. Economic damage

In the estimation of economic damage indicators many methodical mistakes are often made, which occur as a result of disregard to those who suffer the economic consequences of the disaster.

The economic damage from the disaster can be caused to a whole number of enterprises, which are both the potential participants of the disaster and those ones, which have no direct relation to it. All of these entities can suffer both direct and indirect economic losses.

Realizing that the direct economic damage from the emergency situation is expressed in the form of costs and losses caused by this disaster. The direct economic damage to the state includes: the costs of rescue operations, one-time payments to the families of those killed and injured; the costs of purchasing (producing) the essential medical equipment and medicine; payments to rescuers and specialists; restoration of residential buildings; subsidies to firms; immediate elimination of environmentally harmful effects.

The indirect economic damage from the disaster situation includes costs and losses connected with the secondary effects of the natural, technological and social character. Indirect damage can manifest itself over a certain period of time. Indirect damage does not have a clearly defined territorial affiliation and possesses a so-called cascade effect, i.e. secondary series of events generate the next wave of events and, therefore, indirect damages.

The indirect damage to the state includes: non-target expenditures on medical services; social security, support of the affected citizens; reduction of the budget revenues due to the reduction of tax payments from firms that were directly affected by the disaster or as a result of the general decline in the business activity; all above-mentioned costs as composite parts of the direct damage, but formed due to the emergence of other, indirect disasters (mudflows, avalanches, rock falls, accidents, etc.), which were caused by the initial catastrophe.

The costs and losses from direct and indirect economic damages are determined in more detail in [1, 2].

3. Assesment of the catastrophe risk and the economic damage

The cost assessment of the catastrophe risk and the economic damage from the disaster is preceded by the determination of its probable composition, which is a rather complex process. The sequence of the probability assessment of the disaster risk can be presented in the following way.

1. The stationary component of the function of the disaster risk is determined as:

$$X_i = n_i S_i, \tag{1}$$

where $X_1,...,X_k$ is a stationary component of the function of the disaster risk, i.e. the number of objects (people, buildings, cultural values, etc.), which are located on a potentially dangerous territory of the type *i*; $n_1,...,n_k$ is the number of the territories of type *i* with the given probability of disaster risk; $S_1,...,S_k$ is the maximum number of objects, which can be located on the territory of the type *i*.

2. The function of the disaster risk is assessed as:

$$\begin{aligned} &R(t) = \sum_{i=1}^{k} X_i Z_i(t), \\ &Z_i(t) \approx \left\{N_1^i,...,N_k^i\right\}, \end{aligned} \tag{2}$$

where $Z_i(t)$ is the dynamic function of socio-economic content of the territories under consideration; N_j^i is the number of objects that have a dynamic component and a certain probability of a catastrophic breach, $i = 1,...,k, \quad j = 1,...,k.$

3. The function of distribution of the disaster risk probabilities is assessed as:

$$P_{nj}(N_i^j) = \left(\frac{1}{\sqrt{2\pi\sigma_n}}\right) e^{\frac{n_j - \mu_n}{2\sigma_n^2}}. \tag{3}$$

4. The mathematical expectation of discretely distributed random variable is assessed:

$$M(R_i(t)) = Z_i(t)\sum_{i=1}^{k} n_i S_i \sum_{j=1}^{k} N_j^i P_j. \tag{4}$$

5. The mathematical expectation of the squared deviation of the function of the disaster risk from its mathematical expectation is assessed as:

$$D(R_i)t)) = M\left[R_i(t) - M(R_i(t))\right]^2. \tag{5}$$

In this paper, when addressing the cost assessment of the disaster risk we will confine ourselves only to indirect economic damage, since the approaches, methods and techniques of assessment of direct economic damage are studied in other scientific works [3, 4].

A share of indirect damage from disaster is very essential in the total value of economic damage. Its formation is determined by cascade effects in the environment and cyclic relations in the economy. The principle of formation of the indirect losses due to cyclic links in the economy is the following: a power plant is destroyed, because of that a certain amount of electricity is not produced; during the next cycle due to the lack of electricity the machine-building industry does not receive a certain amount of steel, etc.

The above-mentioned facts can be presented in the following formula:

$$U = \sum_{i=1}^{n} \alpha_j^1 P_j^1 + \sum_{m=2}^{M} \sum_{j=1}^{n} P_j^{m-1} \sum_{i=1}^{n(j)} \alpha_i^m a_{ji}^m, \tag{6}$$

where U is the full indirect economic damage in the chain of production losses in the economy as a result of some catastrophic event; P_j^1 is the volume of products j, which were not produced during the first cycle as a result of the disaster; a_{ji}^m is the number of production units i in the cycle m; α_j^1 is the lost profit per production unit j in the first cycle; α_i^m is the lost profit due to the loss of the production unit i in the cycle m.

Since the chain of cycles in the economy is $m \longrightarrow \infty$, it is necessary to solve the issue relating to the sensible ways to determine the number of cycles. The results of practical calculations of cost coefficients of direct, indirect and total material costs in the national economy can give some analogy. Such calculations were carried out during the construction of inter-branch balance. If we use the above-mentioned analogy, it would correspond to the fifth-sixth cycles.

The reduction in the level of the population employment is in direct relation to the cascade of indirect production losses as a result of a disaster. If we assume that there is a direct relationship between the loss of jobs and the fall in production, it is possible to determine indirect damage from the potential unemployment in connection with a hypothetical catastrophic event in some living area.

$$T = \sum_{j=1}^{n} \beta_j^1 t_j^1 P_j^1 + \sum_{m=2}^{M} \sum_{j=1}^{n} P_j^{m-1} \sum_{i=1}^{n(j)} \beta_i^m t_j^m a_{ji}^m, \tag{7}$$

where T is the full indirect economic damage from the chain of employment losses in the economy due to some catastrophic event; t_j^1 is the labor intensity per unit of product j in the first production cycle; t_j^m is the labor intensity per unit of output i in the production cycle m; β_j^1 is the average unemployment payment because of the stoppage of production and inability to produce output j in the first cycle; β_j^m is the average unemployment payment because of the stoppage of production and inability to produce output i in the cycle m.

The assessment of the total economic damage (direct and indirect) from potentially catastrophic events can be used by people, who make decisions during the estimation of the efficiency of anti-catastrophic measures, planning the development of productive forces, project expertise, distribution of limited investment resources among several regions and objects.

4. Emergency and emergency situations

The main criteria of emergency situations should be considered their unforeseen and accidental nature, the inability to control and manage them, the significance of the negative consequences both for people and the environment.

The *emergency* is an accident of a man-made character (connected with the use of technical means, equipment and facilities), of anthropogenic (caused by humans) character, natural and military character causing a sharp deviation from the norms of the processes and phenomena and having a significant negative impact on the human activity, functioning of the economy, social sphere and environment. The most common is the following classification of emergency situations based on the types of occurrences leading to emergencies.

1. Emergency situations of anthropogenic character including: traffic accidents; fires, explosions, threat of explosions; accidents with the release (threat of release) of chemically hazardous substances; accidents with the release (threat of release) of radioactive substances; accidents with the release (threat of release) of biologically dangerous substances; sudden collapse of buildings and structures; breakdown of electric power systems; accidents at waste treatment facilities; hydrodynamic emergencies.
2. Emergency situations of natural character: hazardous geophysical phenomena (earthquakes, volcanic eruptions); hazardous geological phenomena (landslides, mudflows); hazardous meteorological and agro-meteorological phenomena (storms, hail, drought, etc.); hazardous hydrological maritime phenomena (floods, low water levels, etc.); natural fires; infectious diseases of people and farm animals; damage to agricultural crops by plant diseases and pests.
3. Environmental emergencies associated with the changes in the conditions of soil, subsoil and landscape (waste pollution, soil degradation, etc); changes in the composition and properties of air (destruction of the ozone layer, acid rains, etc); changes in aquatic environment (depletion of water resources and others); changes in biosphere (disappearance of animal species, destruction of vegetation, etc.).
4. Emergency situations of military character: related to the use of weapons of mass destruction (nuclear, chemical, biological, ray-beam, radio frequency, infrasound, radiological, geophysical weapons) associated with the use of conventional means of annihilation involving secondary destruction factors resulting in the destruction of nuclear power plants, dams, chemical plants, warehouses, radioactive waste storage facilities, transport communications, etc.

One of the most important issues for the prevention of accidents and emergency situations normalization is the problem of economic assessment of potential and real consequences of these disasters. Therefore, we will study the main methodological issues of evaluating the economic damage from natural calamities and man-made accidents. But before doing that we should clarify the categories of damage in different branches.

In insurance this is the material loss caused the insured as a result of the insured accident. The insurance damage is divided into direct and indirect.

Direct insurance damage is the loss subject to compensation expressed in direct change in the state of the insured property as a result of the insured accident. It can be expressed quantitatively (loss of buildings, destruction of equipment, falling productivity of agricultural crops, loss of livestock, etc.) and qualitatively (deterioration of product quality, depreciation of the fur of fur-bearing animals). Direct insurance losses include costs made by the insured for reducing the damage and salvaging the property.

Indirect insurance damage means secondary, latent losses derived from the direct damage.

Under losses the civil law understands property consequences, which are disadvantageous for the creditor and which occur as a result of delinquency committed by the debtor. They are expressed in the decrease

in property or revenue, which would have been received if the delinquency had not taken place. In other words, damage in the civil law is the lost profit.

Conclusion

For the purposes of this study we should consider the notion of damage in the environmental law, ecological problems and the economy. The specific character of the environmental damage is in its extremely wide variety of content and its manifestations, e.g. the International Law Commission of a grave violation of international legal obligation, which is the fundamental importance for the vital interests of the international community. In economics we do not consider environmental damage mainly as an environmental result, but ecological and economic damage, in other words, the damage assessed economically. Quite often it is referred to the economic damage from the environmental pollution. Such practice has developed because of the fact that in the early stages of formation of the theory of damages the damage from air pollution was studied and evaluated. This state of affairs, when there is a bias of scientific knowledge towards economic damage from the pollution of the atmosphere has been preserved to this day, although it is not as pronounced as it used to be. Under the ecological and economic damage one understands losses reflected in the loss of one's material well-being; loss or deficiency of potential benefits with the money that had been invested into them; loss of non-invested potential benefits; additional costs for the compensation of the incurred losses; inability to use the available resources in the rational way.

The ratio of the values of environmental damage, ecological and economic damage from the violation of the environment and legally significant damage looks like this: legally significant damage plus statutory damage is equal to the total environmental and economic damage; total environmental and economic damage plus some of its unaccounted part (due to some methodical and technical imperfections or failures to carry out its value-based assessment) is equal to the environmental damage.

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