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THE LIFE SAFETY AND RISK MANAGEMENT OPTIMIZATION PROBLEM

Andrii Skrypnyk

Department of Economic Cybernetics, National University of Life and Environmental Science of Ukraine

Corresponding author:
Andrii Skrypnyk
National University of Life and Environmental Science of Ukraine
Department of Economic Cybernetics
Heroyiv Oborony St., 16a, Kyiv, Ukraine, 03041
phone: (+38095) 275 60 36
e-mail: avskripinik@ukr.net

ABSTRACT

It was considered the possibility of optimization approach of the risk management problems based on the stochastic nature of the losses. Since the losses functional magnitude is a random variable, then it was considered the value of losses on a significance level α (losses probability).It was shown decision existence which minimized expected losses. The problem has practical application in coal mining, occasional transportation and other business projects associated with the possibility of life losses.

KEYWORDS
risk management, losses functional, optimization approach, mortality rate, significance level.

Introduction

Usually, the risk management meant managing projects to maximize profits from risk. However, there are a number of problems when you do not maximize profits, but rather to minimize losses. Such problems arise in the case when considering processes that are not directly related to the primary production activity that provides income, but the loss of these processes can significantly impact the financial results.

As you know, there are a number of methods to avoid excessive risk: prevention, control losses accumulate their reserves without insurance transfers, insurance [1]. In developed countries, insurance is usually the main means of avoiding excessive risk [2]. In Ukraine, when the insurance market has not yet formed and virtually no powerful insurance companies, which could shift significant risks, commonly used methods of preventing risks and control losses. Control of losses has two options: to prevent losses (loss prevention) and to reduce loss (loss reduction) [3]. In our research , we will focus on risk management by the method of loss – prevention, which will be based on solving minimum losses optimization

problem [4]. Probability models became the main instrument for decision making in uncertainty conditions [5, 6].

The events of recent years strongly suggest the need to introduce other principles of management in industries associated with the possible life losses. Transport, coal industry and the some other economy branches are extremely dangerous in Ukraine, so neighboring Russia. In this area annually occurring disasters, the consequences of which are covered by the state budget. Donetsk region injuries rate, which can be attributed to the country coal mining leaders, significantly higher than all country index excluding Donetsk region data's (Fig. 1). The mortality rate per 100 000 workers in the coal mining industry is 65 people. Thus, the maximum acceptable risk, which is set by law is only 10/100 000 [7]. In addition, as a combined efficiency and mortality accepted number of deaths per million tons of coal produced. This figure for Ukraine is 2 (one of the worst in the world), while for Poland it is only 0.1, U.S. – 0.02 [8]. This example indicates the extremely low coal mining efficiency providing the high level of risk to employees. It should be emphasized that the various measures, that are intended to rebuilding coal mining by state

support, were non efficient. For ritual activities in 2011 were directed 384 million UAH, coal mines state support – 6.71 billion UAH, technical reconstruction – 1.758 billion UAH, and the emergency ritual measures another 32 million UAH. In addition, the same goal the budget reserve fund was using UAH – 1.3 billion UAH [8].
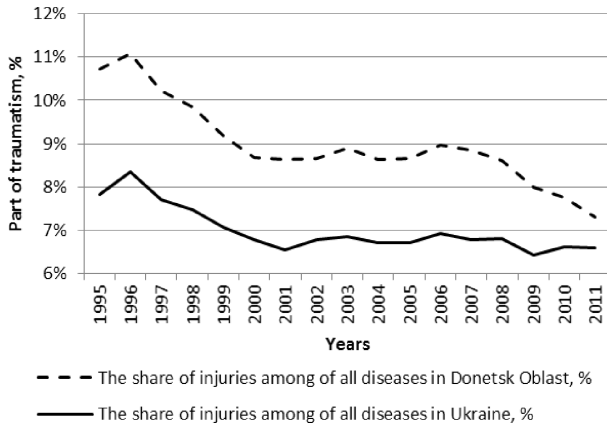

Fig. 1. Traumatism proportion in the Ukraine disease structure at the Donetsk region [9].

Extremely dangerous is an organization of irregular passengers, official visits [10], tourist voyages, transporting sports teams [11], and the organization of work in the areas where the probability of loss of life is essential. Stochastic optimization problem taking into account losses of human life hardly considered, but this problem is close to modern realities. Therefore, the aim of this paper is ruling stochastic optimization problem considering the risk management of real background mortality.

In our view, a significant probability of life losses means that this figure is far above the natural background typical of this subsystem. As subsystems are considered: economic sectors, geographical regions, business environments and so on. Natural background of some country depends primarily on the level of economic development and of its derivatives: the level of medical services, the ecological state of the environment. Of course, it depends on other parameters: the lifestyle, traditions (such as average life expectancy for Japanese living in the US less than that of Japan).

General problem statement

Let $F(x, p(x), S)$ is the potential losses functional of some projects due to the possible implementation of an unwanted event (explosion of methane at the mine, transport crash, catastrophic flood, etc.), that depends on the exploitation cost – x, and the prob-

ability $p(x)$ of catastrophic events that may bring losses$S$. The probability, that varies from the initial value p_1 to the natural background p_0, is a decreasing function of the cost. Exploitation cost determine loss functional by not simple dependence: from one side cost grows increases loss functional, on the other reduce the likelihood of undesirable events and therefore reduce potential losses. Therefore, the formalization of losses functional minimization is:

$$\min F(x, p(x), S),$$

$$\frac{\partial F}{\partial x} > 0; \quad \frac{\partial F}{\partial p} > 0; \quad \frac{\partial F}{\partial S} > 0; \quad \frac{dp}{dx} < 0; \quad (1)$$

$$p(0) = p_1; \quad p(\infty) = p_0; \quad (p_1 > p_0).$$

The first order functional minimization condition:

$$\frac{dF}{dx} = \frac{\partial F}{\partial x} + \frac{\partial F}{\partial p}\frac{dp}{dx} = 0. \quad (2)$$

Accordingly (1), the right side terms have opposite signs, but this does not mean that the first order condition is satisfied under condition $x > 0$. It is possible that the entire range of cost effective dominates the first term (2) – the effective use of funds was not achieved and losses functional minimum is attained with a minimum cost.

Consider the possible variants of losses functional. Since the losses functional magnitude is a random variable, then we consider the value of losses on a significance level α (losses probability is not more then α). Possible losses consist of the following values: x – the cost of the project $p(x)S$ – expected losses due to the implementation of an unwanted event, $z_\alpha \cdot \sigma$ – a deviation from the expected losses on the significance level α, z_α – quintile of the normal distribution, σ – standard deviation.

$$F(x, p(x), S) = x + S \cdot p(x) + z_\alpha \cdot \sigma. \quad (3)$$

Partial decision

Consider this decision as an project with regular transportation sports team by rented plane. The standard approach is to minimize the rent while ensuring the required level of security, which is likely given as acceptable probability of unwanted events. However, the last condition is often neglected and the main criterion is the costs minimization, leading to the use of a substandard aircraft and not enough qualified personnel. Practically, this situation occurs in the coal industry, where the cost paid by the business owner, and disaster relief (second and third term on the right side of (3)) are the state budget expense. In this case, the problem reduces to the mini-

mization of the usual project cost, provided that the probability of disaster does not exceed the limited value:

$$\min x$$
$$p(x) \leq p_0 + \Delta \qquad (4)$$
$$\Delta \to 0,$$

where Δ – positive surplus, which should follow to 0.

Thus, cost minimization is performed only when conditions are not maintaining background probability of unwanted events some value that is less than the natural background typical of the area under study. However, in practice, is the overwhelming cost minimization, and the last condition in practice neglected.

We propose a fundamentally different formulation, which minimizes the total potential costs with the possibility of unforeseen events. For example, consider aircraft leasing decision to transport sports teams. Thus, it is considered that the probability of unwanted events determined by the aircraft renting cost (you can rent "Airbus A-320", or "Yak-42", as was the case with the tragedy in Yaroslavl) (3) – the probability is the inverse function of the aircraft renting cost. Moreover, the probability for any rental cost cannot decrease to zero, but only to the natural background values (except of aircraft and crew, the safety is impacted airport equipment quality, personnel qualification and a number of other factors). So it is necessary to minimize expected losses functional at α significance level:

$$F(X) = p \cdot S + x + \sigma \cdot z_\alpha \Rightarrow \min_x, \qquad (5)$$

where x – the renting (exploitation) cost, p – the probability of unwanted event, S – loss (value of goods including human life with a probability p), pS – expected losses, σ – standard deviation of expected losses, z_α – normal distribution quartile at α significance level.

It is conceded that the probability of unwanted events is a decreasing function of the leasing cost:

$$p = p(x); \quad \frac{dp}{dx} < 0.$$

Also it is considered that the probability of unwanted events cannot be less than the natural background, which is assumed to be $1/10\,000$. The initial probability is assumed to be $1/1000$. This conditions the fractional-linear function are satisfied:

$$p = \frac{a + bx/S}{d + cx/S}. \qquad (6)$$

With next conditions: $p(0) = a/d = 0.001$; $p(\infty) = b/c = 0.0001$.

These conditions are satisfied by fractional-linear function of the following parameters: $a = 1$; $b = 1$; $d = 1000$; $c = 10000$. The costs are measured in units of S. Let $x' = x/S$ (hereinafter $r\ x$), which belongs to the interval $(0, 1)$.

At small p dispersion loss is:

$$\sigma^2 \approx S^2 p \Rightarrow \sigma = S\sqrt{p(1-p)};$$
$$\text{if} \qquad S = 1 \Rightarrow \sigma \approx \sqrt{p}. \qquad (7)$$

Substitute all made assumptions to the expression (5):

$$F(x) = \frac{a + bx}{d + cx} + x + z_\alpha \sqrt{\frac{a + bx}{d + cx}}. \qquad (8)$$

Find the value of the derivative at boundary points of definition of the objective function ($x = 0$, $x = 1$). Meaning quintile of the normal distribution at significance level 0.001 is assumed to be $z_{0.001} = 3$:

$$F'_x(0) \approx -3.8; \quad F'_x(1) \approx 2.$$

Continuous function takes any value that belongs to the interval $(-3.8; 2)$. There is value $x^* \in (0; 1)$, when $F'_x(x^*) = 0$.

Since the entire range of definition $(0; 1)$, the second derivative of the objective function is positive (), then the necessary and sufficient condition for the existence of a minimum loss function. There is at least one losses functional minimum at the interval $(0; 1)$.

Finding the minimum of function $F(x)$ is quite difficult to implement using the first-order conditions, so this function was studied by quantitative methods. Quantitative calculations showed that the minimum function $F(x)$ is: $F(0.0185) = 0.07557$.
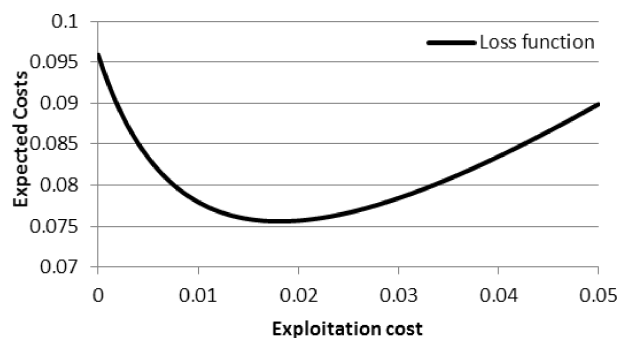

Fig. 2. Losses functional on a significance level 0.001, $p(0) = 0.001$.

That is, if in the case of transportation cost is 1.85%, then the full expected losses, including transportation costs account for 7.56% (Fig. 2), in this case, the likelihood of possible (unwanted) event decreases from 0.001 to 0.00035 – almost three times decreasing. It is possibly the main result because human life is priceless, but despite this undisputed fact,

it is the claimed, that after disasters implementation valuation of human life happening.

Another option payment, when the initial probability equal 0.01, and the minimum is 0.0001 is shown on Fig. 3. In this case, the cost of transport, which minimizes the expected loss and is 5.05%? This same value of expected losses on the 0.001 significance level is 17.7%. Notably, the probability of event decreased from 1% to 0.17%.

Certainly, from the moral point of view, is the preferred approach when minimized costs acceptable level of risk. However, as shown above, in the coal industry despite legally established risk indicators of mortality, their actual excess reaches 550% of established.
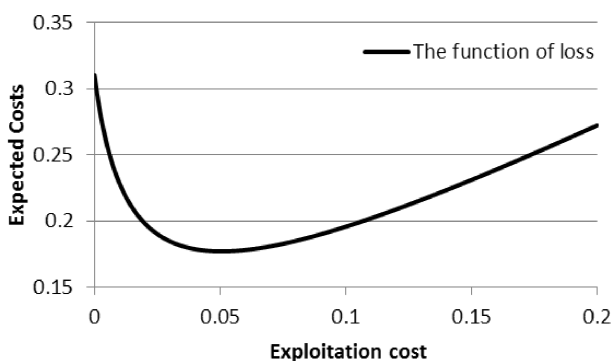

Fig. 3. Losses functional on a significance level 0.001, $p(0) = 0.01 p(\infty) = 0.001$.

Conclusions

In Ukraine, in practice this approach is implemented in most industries, when the functions of safety monitoring are performed by state institutions. On the other hand, the means of production and safety equipment ensures by the owner, and after the worst case scenario realization budget pay all. This scenario prompted the owner to save money at the safety expenses of, and the question of state control in corrupt society is handled with substantially lower material costs than real improvements in safety. That is, purely formally implemented the option to minimize costs for a given maximum-possible degree of risk. However, in reality, costs are minimized

by risk increasing. The situation can be improved by legislative transfer full responsibility for his injuries and fatal accidents to the business owner, and the role of government and public organizations (sectorial trade unions) is to establish standards of fair compensation.

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