NATIONAL SYSTEM OF LOSS COMPENSATION CAUSED BY NATURAL AND TECHNOLOGICAL ACCIDENTS

Approaches, modelling, optimization

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The paper is connected with a problem of national system of loss compensation efficiency assessment. The two-levels imitation model (regions level, federal level) is described. The problem of stochastic programming for the system is formulated. The model includes data base on statistics of natural and technological emergencies in Russia, algorithms for emergencies consequences and loss compensation simulation by Monte-Carlo method, optimization of reserve allocation. Some results of simulation, parametric study and optimization investigation are presented for different schemes of loss compensation.

Introduction

The management of risk of emergencies is the important component of the strategy of sustainable development of Russia. A geographical expansion, broad spectrum of natural risks, feature of a present stage of socio-economic development, and also the global tendencies create a basis for existence and increase of risk of emergencies. The economic losses from emergencies achieve 6-8 % NGP and render serious influence to economy of separate regions and countries as a whole. Only in a 2002 has taken place more than 800 technological and about 300 natural emergencies of various scale. Last years the main accent in emergency risk management is made on development of methods of the prognosis and warning, but simultaneously with it the effective system of loss compensation should function. The experience of developed countries shows, that the different approaches to creation of such system are possible. The research of properties and efficiency of various variants of a system of loss compensation is expedient for executing with use of simulation and optimization models. In the present work the variants of a mathematical model of a national system of loss compensation (NSLC), results of parametrical researches, and also statement of a problem of optimum parameters choice NSLC as a problem of stochastic programming are presented.

System of Loss Compensation Caused by Emergencies

The system of loss compensation is complementary in relation to various mechanisms of emergency management, as first of all is oriented on financing of the costs connected to liquidation of consequences of occurred events, that is concerns to a stage of risk realization, and only in a way is connected to problems of the forecasting and warning. The structure of a system loss compensation essentially depends on a level of socio economic development, legislative basis and national mentality.

The feature of a considered system with reference to Russia is, that it a basis is made by budget financial reserves. In developed countries the insurance is of the most important component system of loss compensation however given mechanism while plays a minor role in Russia by virtue of a small capacity of the Russian market of insurance as a whole and especially of its segment connected to insurance of natural and technological disasters. For example, the participation of insurance in loss compensation of flood in the south of Russia in the summer of 2002, has made all about 2%. In this connection, main burden lays on the federal budget and budgets of the subjects of Russian Federation. In the correspondence with the legislation of Russian Federation there are special financial and material reserves. There are financial fund of Government of Russia, the financial reserves of the subjects of Russian Federation, federal reserve of material resources, and also material reserves of the subjects of Russian Federation, executive authority, local and objects reserves. In the present work the main attention is given to financial reserves.

The sizes of financial reserves of different levels are determined annually. By virtue of boundedness of the budgetary funds there is a problem of the substantiation of a sufficient size of reserves with allowance of emergency statistics for past years and tendencies of a modification. The existing system, when the determination of a size of reserves has not the strict scientific substantiation, is not effective, realization of researches for study of properties of a system, choice of a rational structure and parameters therefore is required. In a situation, when the contribution of insurance is insignificant, and other out of budget sources are small and do not play an essential role, the choice of a structure of NSLC in essence is connected to choice of magnitudes of financial reserves of different levels, proceeding from some criterion of efficiency.

Taking into account complexity of a considered system, the availability of equilibrium processes connected to manifestation emergencies, most effective approach to a research can be a simulation modelling. The study of properties and choice of a rational structure of NSLC can be divided at some stages. A model of an existing system originally is created, for which the parametrical researches are carried out, the potential criterions of efficiency are further determined and the problem of optimization is formulated. The following investigation phases include development of a model with insurance and other methods of loss reimbursement.

Modelling of NSLC

The two-level system of loss compensation is considered which reflects a situation, existing in Russia. The first level describes behavior of financial reserves of the subjects of Russian Federation aggregated in 6 federal regions (Fig. 1). The second level describes a condition of a federal financial reserve.

Figure 1. Map of Russian Federation with divisions into Federal regions.

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(I - Northwest, II - Central, III - Southern, IV – Ural-Volga, V - Siberian, VI- Far East)

The given model is an excess type, as higher hierarchical level (federal) participates in relief of damage only at excess of some significance of damage at lower level of hierarchy (federal regions). The size of a financial reserve D_i for *i*-th of a federal region is defined. In case the total losses from natural and technological emergencies in the given region surpasses D_i, the shortage of financial assets for compensation undertakes from a federal financial reserve D_0. Thus, it is possible to enter parameters of a financial condition for region R_i or federal reserve R_0 , in essence by being algebraic sum of size of a reserve and total loss from emergencies on the end of a settlement period, which is set equal to one year. Depending on scales of consequences all can take place J of emergency kinds, then the appropriate equations will have the following kind.

Federal region

$$R_i = D_i - \sum_{j=1}^{j=J} (Y_{i,j}^{(nat)} - Y_{i,j}^{(tec)}) - N_i^{(inj)} c^{(inj)} - N_i^{(let)} c^{(let)}, \tag{1}$$

where $Y_{i,j}^{(nat)}; Y_{i,j}^{(tec)}$ - total loss in *i*-th region from *j*-th natural and technological emergencies, accordingly, $;

$N_i^{(inj)}; N_i^{(let)}$ - total number people lost and injured in *i*-th region , accordingly;

$c^{(inj)}; c^{(let)}$ - specific size of indemnification injured and lost, $ /person.

In case the total loss will exceed size of a financial reserve, the expression (1) accepts negative significance, which module we shall designate $\{R_i\}_-$.

Federal level

$$R_0 = D_0 - \sum_i \{R_i\}_- \tag{2}$$

The model is adapted to the existing statistical information. The total losses are stochastic parameters estimated by a method of Monte-Carlo on the basis of the statistical data, and also assumptions of functions of loss distribution connected with rare events, number of people lost and injured. The statistical data are grouped according to the classification, legislatively entered in Russia, based on scales of damage, number lost and injured from natural and technological emergencies (Table 1).

Table 1.Classification of emergencies

Parameter	Type of emergency				
	Local	Sub-local	Territorial	Regional	Federal
Number of people suffering W, person	W<10	10<W<50	50<W<500	50<W<500	W>500
Loss Y, thousand $	Y<1	1<Y<5	5<Y<500	500<Y<5000	Y>5000

The estimation of damage is carried out in two stages: imitation of emergency number *j*-type such as in the given federal district K_{ij}; imitation of the size of damage on each realized emergency. For account of number local, sub-local and territorial emergencies, in the assumption of uniform distribution inside the indicated groups, the statistical data for a period 1996-2001 of all federal regions are used. For each $k \in [0, K_{ij}]$ the value of loss in the assumption of uniform distribution inside each class of emergency is evaluated.

For the listed above types of emergencies the number of emergency is simulated parameter. For rare events, the frequency of which realization is less than unit (events annually), the circuit of imitation differs from described above. As the period of regular supervision for emergencies makes six years, the statistical frequencies, given not enough for an estimation of rare events, therefore results of forecasting of frequencies of rare events on all regions are used. For an estimation of loss caused by federal level emergencies is used exponential distribution.

For an estimation of number lost and injured from emergencies of all types also is used exponential distribution with parameter received on the basis of processing of the statistical data on each district.

It is necessary to note, that except for the described above type of NLCS based on an "excess of loss" principle, can be used and other mechanisms of budget financing, for example "quota sharing – excess of loss" system used in Australia [1].

Criterion of Efficiency and Problem of Optimization

Considering the described above model as the financial system, is possible is to entered by a number of the characteristics, which will define efficiency of its functioning. As such criteria, for example, can act distributions of shortage (deficiency) of a federal reserve $F(\{R_0\}_-)$, average of deficiency $E(\{R_0\}_-)$, and also probability of deficiency of a federal reserve:

$$P_r = \Pr ob(R_0 < 0) \qquad (3)$$

The probability of deficiency of a reserve or probability of ruin frequently used criterion, especially in the mathematical theory of insurance, however it does not take into account the size of deficiency of financial assets. By the listed characteristics more complex parameters used in financial risk - management can be constructed. Variance of deficiency of federal funds $Var[\{R_0\}_-]$ as a parameter of efficiency can be used

In case there are assumptions of the allowable sizes of excess of a federal reserve *L*, and also allowable frequency (probability) of such excess *α*, the criterion " value at risk " can be applied:

$$VaR[\alpha, L] = F^{-1}(1-\alpha) \qquad (4)$$

where *F* – function of distribution of deficiency of a federal reserve.

Now the model is conditional-dynamic, that is, it describes behavior of the financial parameters on the end of year. In this case there is no accumulation of the rests of reserves $\{R_i\}_+$. In this case unused means practically remain frozen, that is inefficiently distract from the budget. In this case it is possible to speak about minimization of the rest of regional reserves $\sum_i \{R_i\}_+$ together with search of optimum of other parameters above mentioned.

The problem of an optimum choice of NSLC parameters includes definition of minimum levels of D_0, D_i and maximum of indemnifications $c^{(inj)}; c^{(let)}$ at which the extreme significance of the chosen criterion of efficiency is achieved. Depending on the chosen criterion of a problem can be as one- and multi-criterion.

As the above mentioned criteria depend on stochastic values, the considered problem of an optimum choice of NSLC parameters is a problem of stochastic programming (SP), which can be presented by the way:

$$J(x, y(\omega), z) \to \min_z, \qquad (5)$$

where *J* – chosen criterion of efficiency,

x - determined parameters of system,
y – stochastic parameters of system,
z - optimized parameters.

The area of restrictions of the given problem includes restrictions in the form of equality (1-2) and restriction in the form of inequalities on a range of change of optimized parameters of system. Depending on a choice of criterion of optimization the given problem can be a problem E, V or P - such as stochastic programming. The various variants of a problem of stochastic programming concerning system of loss compensation were considered in work [2].

The classical approach to the decision of SP problem provides reception of the determined equivalent of a stochastic problem and decision it by methods of optimization. However in this case transition to the determined equivalent is inexpedient because of availability in model of rare events. Therefore in the given work the following combined approach to the decision of a stochastic problem (1,2,5) is used. Assessment of criteria (5) is made with the help of Monte-Carlo method for the given initial parameters of system and distribution of stochastic parameters. The main request to a choice of optimization method - absence of criterion function of a problem in an obvious kind (value of criterion is further applied a method of optimization grows out works of a numerical procedure - Monte-Carlo method).

The decision of the given problem is offered to be carried out, by the Hook-Jeavse method and modified method of coordinate descent [3]. The decision of a problem by the Hook-Jeavse method is based on the consecutive analysis of the variants allowing to receive the decision given accuracy, but it requires the significant number of calculations. The decision of optimizing problem by a method of coordinate descent, which is based on the analysis of properties of criterion function, more effectively, however this method (as well as all group of methods of direct search) requires the obvious form of criterion function of a problem and restrictions. In the given work the updating of both methods is made when the criterion function obviously is not given, and its values grows out works of a numerical procedure (Monte-Carlo method).

Program Realization of The Model

The program realization (computer codes) of the given model is carried out by the way of data base-analytical system. The software applications represents open tool system including:

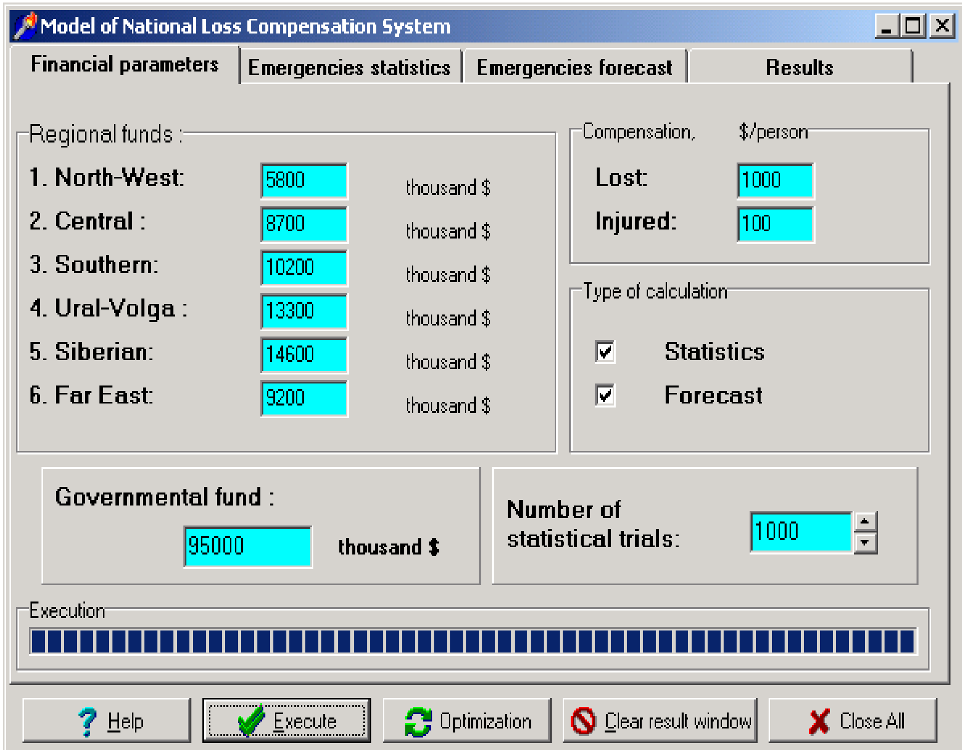
- graphic data base subsystem;
- an analytical subsystem.

The graphic directory subsystem provides

- a storage and viewing statistical and forecast information given about different types of emergencies on all regions, source data on financial reserves and other information in textual and graphic formats;
- input new and editing of the existing information for realization of parametrical researches;
- submission of the initial and settlement information in a format, convenient for the analysis.
- The analytical subsystem provides:
- assessment the number of emergencies, number people lost and injured and damage from emergencies for each federal regions by a method of Monte-Carlo;
- evaluation of probability of deficiency of federal reserve for the given kind of calculation and given parameters of system;
- assessment of expected amount of deficiency of federal reserve for the given kind of calculation and given parameters of system;
- a distribution of deficiency of federal reserve and presentation of distribution in graphic display (histogram).

The software is carried out in Borland Delphi environment and has the convenient user interface (Fig.2). The variant of models allowing to make imitation of a condition of system and to execute parametrical researches is now realized.

Fig. 2. An example of the user interface of the software



Parametrical Study

By the software described above the estimations of the characteristics of existing NLCS were executed, and also the influence of a number of parameters on efficiency of NSLC is investigated. For the fixed values of reserves of federal regions the influence of federal reserve on the expected size of expected deficiency of the federal budget, and also probability of excess executed for the statistical data and forecasting frequency of rare events was investigated. The results of accounts are shown in a Figs. 3 and 4.

Fig. 3. Dependence of probability of deficiency of a federal reserve on its size

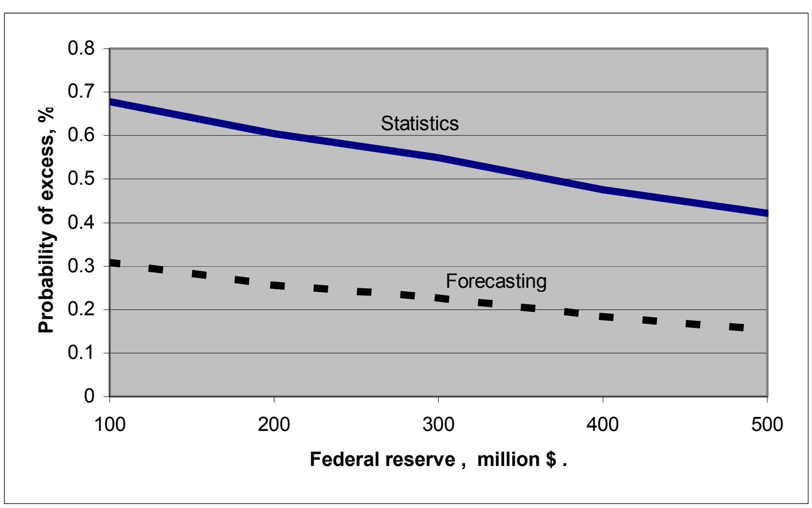
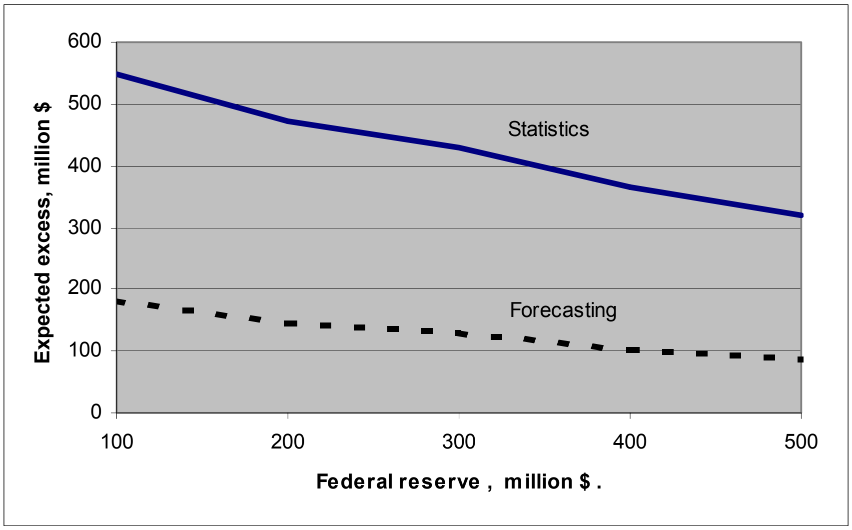


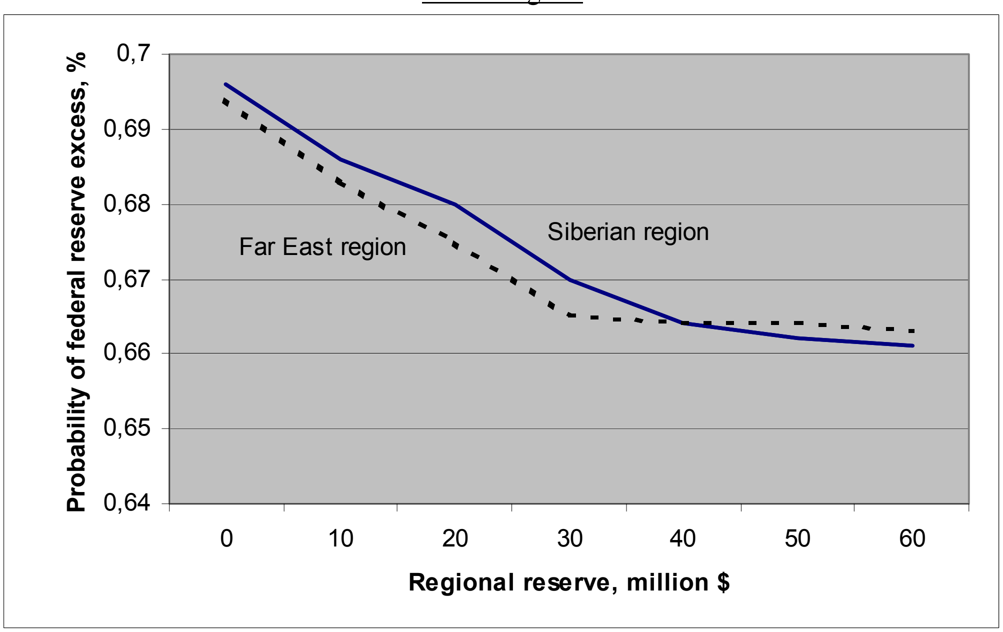
Fig. 4. Dependence of the expected size of deficiency on size of a federal reserve.



As expected, increase of a federal reserve result in reduction of probability of deficiency, and also average values of excess. Besides, the assessments on the statistical data give more pessimistic estimations of NSLC efficiency, than evaluations based on the forecast of rare events.

The estimation of maximum level of reserve of federal regions D_i^* was further executed, at which their values does not render essential influence on the characteristics of system as a whole (conditional - effective value of a reserve). Characteristic behavior of probability of excess of a federal reserve at change of reserves of regions on an example of the Siberian and Far East regions, are shown in a Fig. 5. As expected, the greatest values of D_i, were received for regions with high frequency of catastrophe emergencies (Southern, Siberian, Far East).

Fig. 5. Dependence of probability of deficiency of a federal reserve depending on a reserve of federal region.



For received conditional – effective D_i^*, on all regions the estimation of the NSLC characteristics was executed. The accounts have shown, that the increase of a system effectiveness is possible as a whole at the fixed size of a federal reserve by a choice of value of reserves of the federal regions. At the same time, the effect is not significant, and makes about 8% on probability of excess and about 10 % on expected value of excess. The greatest effect for the accepted type of loss compensation, as it is visible from a fig. 3 and 4, is reached by increasing of a federal financial reserve.

Conclusions

The executed researches show an opportunity of increase of efficiency NSLC of Russia within the framework of existing structure. The further development of system is possible first of all at the expense of introduction of obligatory insurance of state property, natural disaster management, and also use new financial products and creations of the specialized regional financial structure in zones of increased complex risk.

The further development of the model described above will be connected with insurance, development of dynamic model, and also realization of algorithms of optimization of parameters and structure of NSCL.

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