SCENARIO MANAGEMENT OF RISKS OF ACCIDENTS AND CATASTROPHES IN BUSINESS AND ENGINEERING

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Abstract. The stages of development of Management and Risk are described. The scenario management of risks of accidents and catastrophes in complex systems on the stages of designing, debugging and exploitation test and exploitation itself are considered. In the scenario management of accidents and catastrophes risks the personnel and the General designer are taken into account. The uniform approach to the modelling of risks in technical, economic and organisational systems is presented on the basis of substantial description of a SCENARIO of an accident or a catastrophe, and then the construction of models of the risk for the purpose of analysis and management. As the intellectual core for the risk quantitative evaluation and analysis and the scenario management of accidents and catastrophes risk, LP-methods and risk LP-models with groups of incompatible events are used.

Keywords: management, risk, accident, catastrophe, system, logic, probability, model, business, engineering

INTRODUCTION

The phenomenon of complexity of modern technical, economic, organisational and ecological systems, in our opinion, has not been cognised completely scientifically and has not been decided satisfactorily in applied sense. It makes us search for other approaches to the management of the accidents and catastrophes risk.

As the engineering discipline, the management of the accidents and catastrophes risks in complex systems is closely connected with the applied mathematics, as mathematics is those means, which help in most cases to make the adequate statement of a task, and also the precise formulation of conditions and assumptions, at which it is solved possible. However, the fundamental mathematics, based on proved theorems and strictly established laws, *does what it can, but as it must be done*. The applied mathematics, based on some hypotheses, experimental data and common sense, tries to decide problems *that are necessary, but as it can.* The era - w*hat is necessary and how it must be done* - for complex systems has not come yet [1].

Understanding the impossibility of an universal comprehension of the phenomenon of complexity of modern systems, we devote the book only to the questions of *scenario management* of the accidents and catastrophes risk in complex systems at all stages of their life cycle: at designing, debugging and exploitation tests and exploitation itself.

ACTUALITY

The risk consists of two components: the probability of an accident or a catastrophe and the damage. In risk tasks the probability and the damage are calculated by the models of different types: a probability model and an economic one. A risk decrease requires large expenses, and without these expenses, large losses (damage) are possible. Thus, the risk management includes the numerical estimation of a risk as the probability of an accident or a catastrophe and solving the optimisation task of the distribution of resources for the actions lowering the risk. We use the knowledge on the risk by two different ways: 1) passively, in the insurance against accidents fixing a price for the risk; 2) actively, in the management carrying out the actions lowering the risk of separate events.

The reason for accidents and catastrophes in complex systems, created and served by man, are mostly the mistakes at designing, testing and exploitation these systems. These mistakes are the consequence of both the imperfection of techniques and technologies of performance of certain types of work, and the limitation of resources allocated on this work. The problem of the maintenance of safe exploitation is aggravated by new task which has appeared everywhere: by estimation of the risk of

prolongation of a resource of the worn out equipment by monitoring results. In complex systems existence various combinations of initial events-failures of separate elements is quite typical; the probability of each combination is small, but the sum of such "improbable" events is great.

The intellectual core of the scenario management of the risks of accidents and catastrophes in complex systems is made up by the logic and probabilistic methods (LPM) and the risk logic and probabilistic (LP) models with groups of incompatible events (GIE). These components form a different outlook of developers and users, induce them to consider a system as a whole and concentrate their efforts on the decision of paramount tasks, instead of to aiming the resources on minor needs and requirements. The ranking of the complex system elements according to their importance allows to increase the objectivity of distribution of the resources for decreasing the risk of accidents and catastrophes.

THE PRESENT STATE OF AFFAIRS AND HISTORY

Management and Risk have always existed since mankind appeared. Management was carried out taking into account the risk. It was based on intuition, experience and common sense and was empirical. Management provided the existence of man and the community. At later stages of the development of mankind, states appeared. Management was carried out by the Supreme governor of the country based on laws and religion. *The basis of such management in both society and engineering* has remained the same up to now. Later for increasing the effectiveness of management, people introduced some elements of the management mathematical theory and the optimisation mathematical theory into the practice of solving each separate task.

During the industrial revolution, *the classical theory of control* (regulation) by separate mechanisms, devices and processes, based on the description of dynamics of objects by differential equations, was created. The risk control was taken into account indirectly by the criteria of stability, possibility of resonant phenomena, destruction, etc. The success of the classical theory of control is enormous, for example, the control of the start and movement of a space ship.The scientists F.R.Bellman,H.Chestnut,R.W.Mayer,L.S.Pontryagin, Ya.Z.Tsipkin, etc made the most valuable contribution in creating the classical control theory.

In period 1939 - 1945 for the purposes of management such mathematical disciplines as Operations Research and Game Theory are appeared. The Operations Research is based on mathematical modelling of processes and phenomena and begins with the analysis of a criterion of efficiency of decision. The Game Theory is the theory of mathematical models of acceptance of optimum decisions in conditions of a conflict and uncertainty. The mathematical models had, as rule, discrete variables, were described by the system of the algebraic equations and had the economic contents.

During the Second World War for the purposes of management there appeared such mathematical discipline as *Operations Research* using the system approach to task statement and decision-making .Later this discipline almost completely became used only for the decision of optimisation tasks by methods of linear and non-linear programming. The methods for the decision of separate tasks of optimisation with the criteria of economic efficiency (the transport task, cutting the materials, etc.) were created.

Immediately after the Second World War *the control cybernetic theory* (Norbert Wiener) appeared. According to observable parameters at the input and output of an object the mathematical model of an object - "a black box" was constructed. Such control was used for the solving separate tasks of optimal control. The risk of such control was considered as the failure probability in the achievement of the purpose because of the non-adequacy of a model and the presence of white noise.

In 1952 years *the risk management science of investments* (Harry M. Markowitz [2]) appeared. For the first time the choice task of an optimum portofolio of valuable papers was formulated and decided. . “The models of averages and dispersions" were used. For each securities in a portofolio it took into account: the expected returns, as mathematical expectation, and risk, as standard deviation and uncertainty measure of expected returns. Such new concepts as the diversification, the indifference curves of the investor, achievable and effective sets of portofolioes were introduced. The contribution by Harry M. Markowitz was important and he got the Nobel premium for economy in 1990.

The portofolio optimization task of valuable papers had two criteria: expected returns and a portofolio risk. The normal law of distribution for expected returns of each paper and all portofolio was used.

The theory Harry M. Markowitz had such large success and development, that other approaches to risk research in business with discrete non-parametrical distributions of casual values were paralysed.

With the appearance of computers *information management* or management information automated systems came into being. These systems have: a well-structured database, an information technology with the window interface, software for solving a certain type of optimisation tasks, expert systems for decision-making, software for making reports and illustrations. It allows to give out any information for inquiries or use it for the decision of tasks quickly, to allocate the area of optimal allowable decisions, to choose the most effective decisions. The final decision is made by the main expert. In management information systems the tasks of a risk numerical estimation were not decided.

A new step in the development of the management theory was the appearance of *the situation management based* on logic-linguistic models ([3], D.Pospelov). It was shown, that the management of complex objects is absolutely impossible without using qualitative semantic sense information, which can not be expressed quantitatively. T*he logic, sets and logic connections of objects and events* were introduced into the theory and practice of management. The following was suggested: various ways of the description of observable situations, using the languages with developed semantics; various methods of the construction of knowledge models, allowing to reflect in these models qualitative ratio and laws; various procedures of decision-making in management on the basis of logic-linguistic models. A range of considered applications included the tasks of operatively-dispatching character for seaports, airports.The risk tasks in the systems of situation management were not decided.

Of much importance was the creation of *logic and probabilistic methods* ([1,4], I.A.Ryabinin) for quantitative modelling and analysis of reliability and safety of structurally complex technical systems. These logic and probabilistic methods (LPM) are a special section of mathematics, connected with logic-mathematical calculus . These methods allow to range the elements of a complex system according to their importance. These methods have passed approbation in the real projects of the naval fleet. They have become the intellectual core of management systems for reliability and safety in complex technical systems.

The development of logic and probabilistic methods was the creation of the generalised LPM ([5], A.C.Mojaev), which used all the logic connections (AND,OR,NOT) and introduced the schemes of the functional integrity. It has allowed to make the scenario for the successful or unsuccessful functioning of any technical or organisational system as the count using also the fictitious tops. It was created the program system for the for quantitative structure-logical analysis of the stability and effectiveness of structure-complex systems. It has successful used for years for training the students and solving the different applied tasks of analysis and management.

On the basis of logic and probabilistic approach *the risk LP-modelling and LP-analysis theory with groups of incompatible events* (GIE) ([6-8], E.Solojentsev) was created. It has allowed to model and analyse risks in the systems, which elements and the system itself have several states, and to apply LP-models with GIE for quantitative modelling and the analysis of the risk not only of technical, but also of economic, organisational and ecological systems. The states of elements in the systems were described both quantitatively and qualitatively, that is semantically.

In 1997 years the work on the strategy of risks management with he attraction of the new approaches from the area of fundamental sciences began. *The State Program: "Safety of Russia" has been* developed. In the book of the authors of this program "Management of risks" [9] special attention is paid to the problems of the risk management strategy. The authors' concept is the following. On the basis of accumulated experience a new science – the mathematical theory of safety and risk can be created. This theory must lie between the level of taking political decisions and strategic decisions as laws and the level of the development of concrete technical systems. As a methodical basis for creation of such a theory, they offer to use non-linear dynamics, the theory of bifurcation and chaos. The offered methodical base for the theory of risks is probably true for modelling of the earthquakes and the snow avalanches, but it is wrong for structure-complex human-machine systems.This statement is erroneous and it initialised the writing of the present book.

Scientific novelty of the curried out researches is in the following:

1. The uniform approach to the modelling and analysis of risks in technical, economic and organisational systems is discussed on the basis of substantial description of a SCENARIO of an accident or a catastrophe, and then the scenario-based construction of structural, logic and probabilistic models of the risk. It allows to realise the scenario management of risks in complex systems. The existence of different risk theories in various subject areas is not justified. Accidents and catastrophes, as a rule, are

caused by the combination of system defects (design, manufacture, organisation), exploitation defects (mistakes of the personnel).

2. As the intellectual core for the risk quantitative evaluation and analysis and the scenario management of accidents and catastrophes risk , LP-methods and risk LP-models with groups of incompatible events are suggested. The traditional "pure" mathematics and the non-linear mechanics try to explain everything by theorems. However still the greatest contemporary scientists J. Von Neumann and Norbert Wiener knew, that the complete confluence of theory and practice is indispensable; they could not be satisfied by cachetic concepts of mathematicians, lacking in practical value. Real complex technical, economic and social systems cannot be described with the help of differential equations.

3. In the scenario management of accidents and catastrophes risks the personnel and the General designer are taken into account. In such systems as nuclear power stations, starting rocket complexes and banks emergencies in general are caused by people. The role of the style, concepts and methods of the General designer in solving the risk tasks is quite great.. Out of a variety of new ideas he has to choose those which have the scientific and techno-logical substantiation and can be realised at given moment. He must not lose the general orientation and miss the most relevant details as well. Only by full-size tests and modelling one can became confident in the reliability of chosen decisions. The great Leonardo da Vinci (it is known) put forward a set of new ideas, including a helicopter, a parachute, and a ball-bearing. However the mankind needed five centuries to put them into practice.

4. The methods and models of scenario management of risk *at the stages of designing, debugging and exploitation tests and at exploitation* itself are described. The safety of complex systems, that are generally considered as complex human-machine systems and systems with various states of elements and the system itself, is formed at all the stages of the life cycle.

PRACTICAL SIGNIFICANCE

The appeal of scenario management of accidents and catastrophes risk for economists and engineers consists in its exclusive clearness, unambiguity and large opportunities for the analysis of influence of any element on the risk of accidents and catastrophes. The large number of examples is given, because examples teach sometimes better and faster than dry theory. Though complex mathematical methods are used in the book, it is intended for engineers and economists. All problems are discussed from the point of view of their practical application.

The work consists of several chapters, which have the following contents.

1. Technogenic accidence and catastrophes of the XX century. The data about great accidents and catastrophes, the most dangerous branches of industry, the amount of risk and damage of some objects are resulted. The accidents and catastrophes' sources are considered, the state safety program is presented, the methods of non-linear mechanics and LP-methods for modelling catastrophes are discussed. The stages of development of Management and Risk are described.

2. Men and risks. The frauds in business, the mistakes of attendants, asymmetrical actions of terrorists, hakker attacks on information networks, the position of personnel in the modern industrial civilisation are discussed.

3. Principles of risk management at designing. The style , concepts and methods of the general designer in describing the scenarios of accidents and catastrophes and risk management are discussed. General scientific knowledge, models and rules used in the area of risk are stated. Non-parametrical distributions of casual events are described; the essence of the Okkama Razor rule and the physical approach to the tasks of risk is explained; the scheme of risk management as a complex object is given, the task of minimisation of the number of decisions and the concept of acceptable risk is stated.

4. Risk management at debugging tests. The essence and the condition of debugging tests are described, the losses at debugging are given, the normative documents and the results of the debugging processes analysis are discussed, the principles of debugging management are stated, the debugging management scheme is described, the technology of debugging and its procedure is described, the scenarios of accidents and the example of the development of debugging tests program is supplied. A conclusion is made, that the mistakes one to the poor-quality of debugging tests and resources limitation are quite possible.

5. Risk management at exploitation tests. The technique of forecasting failures at exploitation tests is stated, the methodology of critical questions is described. The sources of critical questions are described, the methodology of using critical questions for working out the test program is described, the scenarios of failures and critical questions are given. The idea of the evolutional exploitation tests is described. The principles of the choice of working conditions for tests are presented.

6. Risk management at exploitation based on monitoring. The problem of destruction, deterioration and aging of the equipment in exploitation is considered. The role of monito-ring in society , economy, sports, medicine and engineering is discussed. The examples of the scenarios of failures and the monitoring of risk of functioning of a starting rocket complex and risk estimations of the worn out power equipment of resource prolongation are given.

7. The logic and probabilistic safety theory. The basic definitions of the safety theory are represented. The logic and probabilistic theory of the safety and the reliability is stated. The equations for all minimum paths of successful functioning system and for all minimum sections of system failures are presented. The methods of orthogonalization of logical functions are considered. The example of modelling and analysis of safety are given, the advantages of safety LP-models are considered.

8. The LP-risk theory with the groups of incompatible events. The scenarios of failure, events-signs and events–grades are considered, the basic equations are presented, the connection of the Bayes' formula and GIE is explained, the definition of the price for a risk is given, risk dynamic LP-models are described, estimations of accuracy and robustness of LP-risk models are made.

9. Identification of risk LP-models with GIE. The task of the LP-failure risk model identification based on statistical data is set. The methods of the LP-risk model optimisation/ identification are stated and investigated, the task of defining global extreme is set, the results of computer researches are discussed .

10. Analysis of risk. The purposes, methods and results of statistical and combinatorial risk analysis are given. The method of LP-risk analysis by the contributions of events-signs and events–grades to the object risk, to the average risk of a set of objects and to the accuracy of LP- risk model are presented. These methods of analysis are a base of risk management.

11. SOFTWARE for the risk analysis and management. The following is described here: intellectual AWS' for safety management, Software for identification and analysis of LP-risk models with GIE, Software for a structural-logic modelling of risks , Software for orthogonalization of L-functions based on cortege algebra.

12. Risk LP-models in business. A credit risk LP-model and the analysis results of the bank credit activity is given. The scenarios, the bribes LP-model and the frauds LP-models in business are considered. The management of the condition and development of a company according to the risk criterion is considered. The scenarios and the risk LP-models of the interaction of banks and companies and the risk LP-model of the loss of quality and the market are described.

13. Risk LP-models in engineering. The scenario and the LP-model of an explosion in a submarine are presented; the safety control system of a nuclear reactor is described; the task of the risk at the resource prolongation of the power equipment is discussed; the review of the known applications of risk LP-models in engineering is made.

14. Personnel and risks at a nuclear-dangerous plants. The unsolved problems are discussed; the approaches by Bernoulli and Columb to using the knowledge on risks are discussed. The peculiarities of financing the processes of the risk management are described, the parameter for the regulation of reliability of engineering and man is given, the account technique of natural and technogenic accidents is described, the risk of the poor-quality organisation of work is discussed.

The work is intended for experts and scientists working in the area of modelling, quantitative estimation and analysis of risk as well as the risk management in technical, economic and organisational systems *on the stages of designing, debugging and exploitation tests and exploitation itself.* It will also be useful for the students and post-graduate students of economic, financial and technical universities.

REFERENCES

1. Ryabinin I.A. *Relibility and safety of structure – complex systems*. Sankt-Petersburg, Politechnika, 2000, 360 p.
2. Harry M. Markowitz, «Portfolio Selection», Journal of Finance, 7, No1 (March 1952).
3. Pospelov D.A.. Logic and linguistic models in the systems of management . -

Moscow: Energoizdat, 1981.- 232 p.
4. Ryabinin I.A., Cherkessov G.N. Logic and probabilistic method of research of reliability of structure - complex systems . Moscow: Radio and Swyaz, 1981.
5. Mojaev A.S. Modern condition and some directions of development of logic-probabilistic methods of the analysis of systems // Theory and information technology of safety simulation for complex systems. Issue.1 -5 / Edited by I.Ryabinin and E.Solojentsev . St.Petersburg.: IPMASH RAS , 1994-95.
6. Solojentsev E.D., Karassev V.V., Solojentsev V.E. Logic and probabilistic models of risk in banks, business and quality / Edited by E.Solojentsev. St.Petersburg: Nauka,1999.-120p.
7. Solojentsev E.D., Karassev V.V. (2001) Risk logic and probabilistic models in business and identification of risk models. - Informatica 25 (2001) 49-55.
8. Solojentsev E.D., Karasev V.V. Identification of logic and probabilistic models of risk of structure-complex systems with groups of incompatible events. - Automation and Remote Control, No 3, 2002.
9. Risk Management (Stability development, Synergetic). Moscow: Nauka, 2000. – 431 p.
10. Kulik B.A. Representation of Logic Systems in a Probabilistic Space; in Term of Cortege Algebra. 1. Elements of Cortege Algebra.. 2. Measurable Logical Systems. – Automation and Remote Control, 1997, No1, p.126-136; 1997, No, p.169-179.