Development of models for risk analysis and optimization of risk reduction costs

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Abstract. The article deals with the actual problem of risk analysis and management in the technosphere. Proposed and developed: classification of risks (events, variations, bifurcations); risk analysis structures; risk management structure of variations and bifurcations; models for optimizing the cost of risk management.

Complex systems that include components belonging to technical, natural and anthropogenic environments are subjected to risks \( R \) induced by uncertainty. This is the most pressing problem of our time, in particular with the reduction of the resource base and nonlinear complication of the interaction between man and the manmade environments [1-3]. New national and international standards on risk management are being created [4-6]. Certain aspects in these standards are not sufficiently substantiated by the scientific and methodological basis [1, 2]. A more detailed study of the risks \( R(\tau) \) allows introducing the classification of risk that takes into account the factor of time \( \tau \):

- risks of hazardous events (that are slightly dependent or conditionally independent of time);
- risks that change significantly over time, i.e. risks - process variations;
- risks with dramatic dynamic changes over time, i.e. risks with the effects of bifurcation and with the rapid reaching critical levels of risks \( R_c(\tau) \) (figure 1).

![Figure 1. Classification of risks as a function of time](image)

The following architecture of risk analysis is proposed to develop the existing models [1-3] (figure 2):
• identification of threats or an array of possible events (processes with non-robust variation; processes accompanied by bifurcations);
• determination of system vulnerabilities (taking into account the factor of time, figure 1);
• loss estimation.

Sociotechnical systems respond (figure 2) to threats, passing into the following states of vulnerability: stable, uncertain, unstable, overly unstable (response to a hypothetical extreme threat). Due to the inconsistency of the socio-technical system with threats the following losses can be inflicted: negligible, acceptable, excessive and hypothetical (figure 2).

Figure 2. Risk Analysis Framework – Events.

Appropriate socio-technical solutions are implemented to prevent and counter risks [1-3]. Due to the negligible response time risks of bifurcations present a particular threat [1, 2]. A methodology for preventing and parrying bifurcations of processes is proposed. It can be illustrated by a graphical model (figure 3).

During the implementation of the process for which the requirements are established, on the basis of the risk analysis, the causes are determined and actions are taken to prevent, and in the event of unacceptable variations and bifurcations of parrying, as well as the intended actions are verified and validated.

If the arising bifurcations cannot be prevented by the provided preventive actions, in order to achieve the required output of the process with an acceptable nominal time value and its variation, an emergency action plan is implemented, after the implementation of which the acceptability of variation and prevention of bifurcations is achieved. Re-verification and validation allows the achievement of appropriate process output requirements despite bifurcation and satisfaction of process output customers and other interested parties (figure 3).
The optimization of costs is the most urgent problem in the implementation of risk-oriented thinking in practice [1, 2]. This is due to the fact that the costs of risk management have arisen as a new resource component.

To reduce the cost of products and processes, it is necessary to establish the optimal ratio between the types of costs and losses (figure 4). A model of cost optimization for achieving acceptable risks was proposed [3] based on the assumption of a close to hyperbolic relationship between each pair of components of identified groups of costs for achieving compliance in risk-oriented thinking. In this case, the minimum value of total costs is achieved when the three identified components are equal.

When implementing projects to create products, a methodological problem of adequate application of risk analysis techniques arises [3]. Technicians that perform the technical risk analysis within the traditional approach are not informed about strategic plans at the macro level. For example, they may not be aware of both the prospects of a particular project and plans for allocation of resources for implementation of measures to achieve the acceptability of risks [3]. To improve the risk analysis
methodology, it is necessary, first of all, to introduce $R(\tau)$ risks for systems or components into the analysis, failure of which results to the maximum damage [7]. Thus, for practical use, a criterion has been defined for allocating resources for implementation of measures to prevent and counter risks.

![Figure 4](image)

**Figure 4.** Cost optimization model to achieve acceptable risks.

In addition to event risk analyses (when using the FMEA methodology) [1, 2, 4-10], an appropriate methodological support has been proposed [7] to take into account the risks of variations and bifurcations, both to achieve conformity in quality [9, 10], and when analysing various aspects of risks (bribery [4], occupational safety [5] and energy efficiency [6]) in the supply chain [8].

The presented graphical models allow creating and improving international and state standards - descriptive risk management models that are widely used in practice for the effective and efficient functioning of socio-technical systems [7-10] for various sectors of the economy (mechanical engineering, defense production, etc.).

**References**

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